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TOWARD IMPROVED MAINTENANCE TRAINING PROGRAMS:

THE POTENTIALS FOR TRAINING AND AIDING THE TECHNICIAN

Human Factors Laboratory
Naval Training Equipment Center
Orlando, Florida 32813

July 1981

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NAVAL TRAINING EQUIPMENT CENTER
ORLANDO, FLORIDA 32813

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TOWARD IMPROVED MAINTENANCE TRAINING PROGRAMS: THE POTENTIALS FOR TRAINING AND AIDING THE TECHNICIAN

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A compilation of the papers presented at the Third Biennial Maintenance Training and Aiding Conference sponsored by the Naval Air Systems Command (Code AIR 340F) and hosted by the Human Factors Laboratory, Naval Training Equipment Center. The papers address the role of job aiding and performance in the capability development and training of the maintenance technician. The integration of aiding and training appears needed in meeting the maintenance requirements of the Navy's increasingly sophisticated equipment.

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MAINTENANCE TRAINING AND AIDING: AN OVERVIEW

Dr. William J. King & Dr. Paul E. Van Hemel[1]

Naval Training Equipment Center
Orlando, Florida

A BREACH

In the overview of an earlier conference in this series, King (1975) proclaimed what was then a "surprising" discovery that there was very little exchange between developers/proponents of maintenance training and their counterparts in maintenance aiding. It remained until this Third Biennial Conference for us to call a meeting devoted exclusively to discussing that schism, and for us to realize that these two areas of maintenance support have for several years been developing along separate paths.

The dichotomy is real! This was confirmed by at least two prominent authors among those of the present conference papers who describe several indications of potentially serious impediments to the achievement of an overall integrated human factors effort. Inaba points out, for example, the mutual distrust between training researchers and aiding researchers and that human factors researchers and human factors practitioners have for years stood as breeds apart in terms of their approaches and solutions to maintenance problems. Blanchard cites material by Melton dating back to 1962 acknowledging that "psychotechnologies associated with personnel selection, training, and human engineering were developed more or less in isolation from one another." Further, Blanchard notes that specialists tend to promote their own parochial interests rather than an integration of concepts.

[1]Both are now at Ergonomics Associates, Inc., Orlando, Florida.

ATTEMPTED HEALINGS OF THE BREACH

In his talk at the conference, Dr. Blanchard presented Figure 1 as an Integrated Personnel System Approach (IPSA) to improve maintenance training through trade-offs among the depicted elements. The concept is, of course, very reminiscent of the Personnel Subsystem approach developed by the Air Force in the 1960's to integrate Human Engineering, Training, and Personnel Management. Just as Personnel Subsystem elements may fall into natural groupings (DeGreene, 1970), elements of IPSA might also be grouped to reflect: (a) the types of technologies that fall in the same professional category in the human factors field, and (b) roles of current Navy commands.

A natural grouping might allow a concept such as that presented in Figure 2, which represents a simplified approach that could be implemented and working in the current Navy research community within a very short period of time. The approach of Figure 2 is workable in the sense that there exist Navy research organizations with expertise and experience to permit ready assumption of primary responsibility for the design research groupings of the figure. For example, the Naval Air Development Center is well-versed in Human Engineering Design of Air Systems, the Naval Training Equipment Center knows Training and Aiding System Design, and the Navy Personnel Research and Development Center is certainly expert in Personnel Pipeline Design. The overall integration function could be served by an appropriate organization in the Naval Materiel Command.

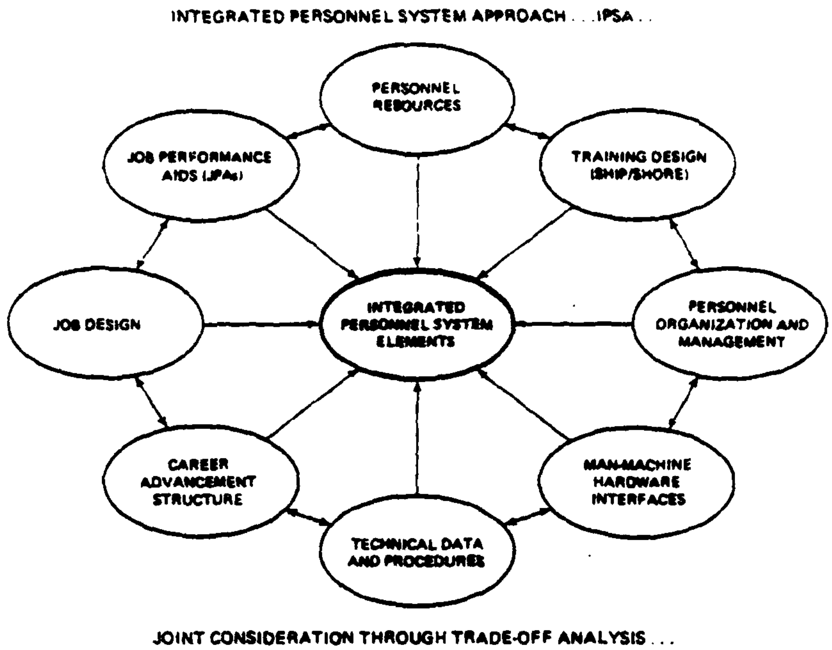

FIGURE 1. Integrated Personnel System Approach presented by Blanchard.

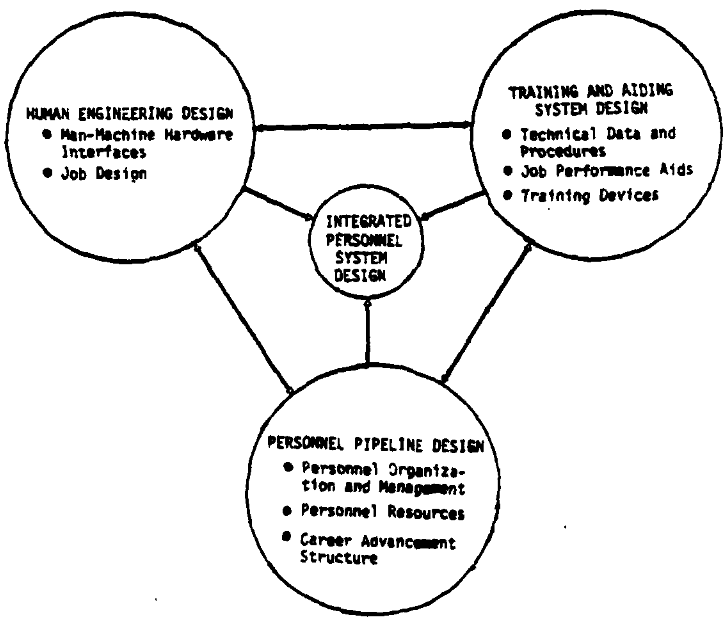

FIGURE 2. Integrated Personnel System Design.

The Integrated Personnel System Design of Figure 2 is presented here solely as a working level suggestion for one way of improving the lot of the Navy technician. The suggestion must obviously be weighed against other requirements which are beyond the scope of this conference and certainly that of the present paper. In any event, as Blanchard notes, the case for a systems approach is compelling; indeed, we may be able to foster such an orientation by taking advantage of such natural clusters of interest and experience as those suggested in Figure 2.

DECENTRALIZATION OF TECHNICAL TRAINING

Two papers from distinctly different sources sounded an interesting de-integration theme, viz., technical training needs to be decentralized to on-the-job training (OJT). Carpenter-Huffman of Rand Corporation pointed out some of the limitations of formal training in *schools and advocated* that maintenance OJT be formally administered by operating commands within units separated from maintenance production, such as the Navy's FRAMP (Fleet Readiness Aviation Maintenance Personnel). Klesch of the Army Training Support Center described the advantages of the Army's Skill Performance Aids program to support on-the-job training and job performance through improved technical manuals and extension training materials.

Decentralization is a laudable approach to relieving the almost unmanageable technical training burden within DoD. However, unless we can provide appropriate delivery systems such as adaptive self-paced instructional media, there will be a repeat of the problem underlined in Carpenter-*Huffman's paper*, to wit, "The most common single complaint about OJT on the TAC questionnaire was that those assigned as trainers were inadequate as teachers." (Carpenter-Huffman, pg. 13) With appropriate delivery systems, the teaching skill of the individual responsible for technical training in the fleet/field is not such a limiting factor. In other words, professionally-prepared materials delivered via professionally-produced media should be effective for training regardless of who ultimately turns on the power switch.

A TECHNOLOGY BASE FOR MT&A

That a powerful technology base is available for training and aiding the technician is illustrated by the conference papers of Frazier, DePaul, & Towne. In endorsing such approaches, we must always be mindful of the rather low current standing of CAI (Computer Assisted Instruction) in the military community. Unfortunately, it does little good to point out that the first users of fire undoubtedly learned the hard way about the dangers of CO poisoning and asphyxiation. The point is that CAI and other forms of computer based instruction could be a boon to technician training and aiding the world over if we can just be allowed to bring the potential solution to bear on the problem.

AN OMB 109 SOLUTION

Other themes discussed at the conference had to do with management solutions for getting MT&A delivered to the technician. It is no surprise, of course, that management issues would arise at a conference where, even on the last day, there were no fewer than 23 Ph.D.s in attendance. What was interesting was the theme that "nobody is implementing our technology" and that some rather innovative solutions were proposed.

One was to the effect that since OMB 109 specifies that requirements be articulated by government and solutions be proposed by industry, why not just abandon all our feeble attempts at internal technical training by the military and contract

out all of it? Or further, why not even let industry recruit and select the large numbers of technical troops to fill the skilled jobs that go begging in the military?

Such topics and discussion are presented here only as unexplored questions. They would require analysis and could serve as themes for entire MT&A conferences in the future.

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TECHNICIAN TRAINING AND AIDING: WHERE THE DEFENSE READINESS BUCK STOPS

Dr. Paul E. Van Hemel
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ABSTRACT

The outstanding capability of U.S. industrial contractors has produced revolutionary developments, new subsystems, and sophisticated design in weapons systems and other equipments to meet demanding military requirements. The result has often been overly complex and expensive systems that leave much to be desired in the way of reliability. The sophistication of U.S. weapons systems has tended to generate higher maintenance personnel and training costs and higher support costs; it has also made the use of such remedies as Automatic Test Equipment (ATE) mandatory in many maintenance systems. The proliferation of increasingly sophisticated equipment on which readiness depends has increased further the need of highly capable maintenance personnel. *The readiness of our defense depends on what may be thought of as* the "readiness" of maintenance technicians, namely, the availability of maintenance personnel who can return a malfunctioning system to the operational state. The availability of such personnel is directly dependent upon our capability to train them and to provide them with timely and convenient access to technical data. Defense *readiness thus ultimately* hinges upon effective training and aiding of maintenance technicians.

The systems on which people depend for various necessities have become more complex with advances in technology. Not surprisingly, military systems provide a prime example of the trend of increasing complexity. One of the most striking measures of that trend is cost, although other measures are certainly possible. Gates, Gourary, Deitchman, Rowan, and Weimer (1974) used cost as a measure, presenting data illustrating increasing complexity over seven decades as reflected in costs. Figure 1 shows the cost of several military aircraft as a function of year of introduction. From the figure, it is evident that combat aircraft costs have grown steadily over the years following 1910.

If cost measures alone do not convince you that today's military aircraft are more complex than those of earlier years, it may be of interest to examine what happened to aviation electronics during the period from 1950 to the early 1970's when miniaturization was shrinking electronics' size and cost almost daily. During that period, the weight of electronics carried by attack and intercepter aircraft actually increased severalfold and the cost of electronics rose from about 10-20 percent of total aircraft cost in the 1950's to 20-30 percent in the late 1960's and early 1970's (Gates, et al., 1974).

The increase in complexity of systems is reflective of American creativity and fascination with new technology. In a recent analysis of technology and the military balance, Head (1978) contrasted the U.S. Research and Development (R&D) style with that on the Soviet side. Head characterized the effect R&D has on our competitive market economy in a way that at first inspires confidence, especially when compared to the Soviet system. U.S. industrial producers draw upon a superior technology base, conduct civil and military R&D simultaneously, and satisfy a high civil demand for advanced technology products. The American R&D process is more fragmented than its Soviet counterpart, more open to citizen influences, more responsive to arguments over arms controls implications, environmental impact, and a fair allocation of government contracts. Yet, the U.S. system operates amazingly well because of the skills, flexibility and ingenuity of its scientists, engineers, and technicians (Head, 1978).

Weapons development in the U.S. is oriented toward high performance, largely as a result of the responsiveness of our R&D to demanding military requirements. U.S. industrial contractors respond to those requirements with proposals for revolutionary developments, new subsystems, and sophisticated design (Head, 1978), and the cycle of increasing complexity continues. In the Soviet system, proscription of all but centrally-approved designers' handbooks, lack of sophistication in production technology, low technical level of Soviet troops, and other limitations provide seemingly reassuring constraints on their weapons

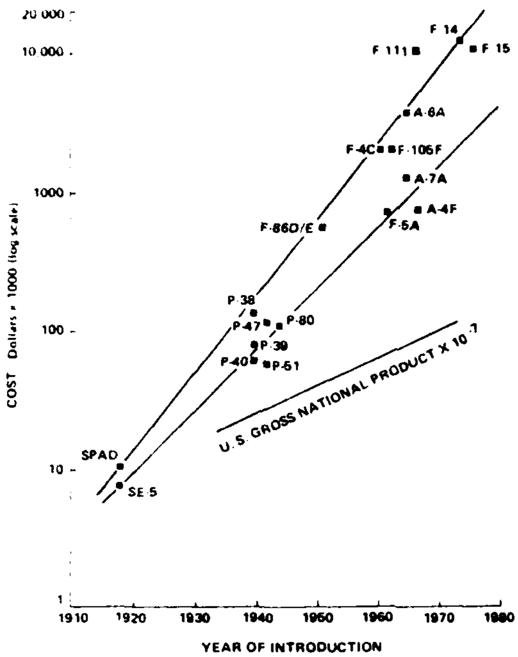

FIGURE 1. Cost of Indicated Military Aircraft as a Function of the Year of Introduction (Adapted from Gates, et al., 1974)

design.

In my comparison of U.S. and Soviet R&D styles, I have implied that the superiority of the U.S. system may be more apparent than real. You might reasonably expect to find a relationship between complexity of weapons systems and military capability, but the relationship you expect may not be the one that actually exists. Head (1978) warned that superficial comparisons between supposedly equivalent U.S. and Soviet weapons systems can delude policy makers into thinking that "technological superiority" guarantees peace. Head was concerned that at some point greater quantity of lower-quality weapons confers the capability to overwhelm the highest quality defense. I think there is more cause for concern that one may be lulled into thinking that complexity of weapons systems guarantees technological superiority.

Let us examine the relationship between system complexity and system reliability using cost as an index of complexity. Figure 2 shows field reliability as a function of unit production cost. Clearly, as system cost and associated complexity increase, reliability decreases (Gates, et. al., 1974). The relationship is not perfect, but the trend is obvious. With the exception of equipment maintained under warranty, the highest reliability shown in the figure is for the $372 51Z3 Marker Beacon, and the lowest reliability is for the $312,000 AWG-10 Radar and Fire Control. Gates, et al. (1974) noted improved reliability under special programs, such as maintenance under warranty by the contractor for the Delco Carousel IV inertial navigator, and argue that such programs can promise alleviation of the reliability problems. At the same time, they point out that an annual 15 percent rate of growth in reliability of electronics as technology advances is barely keeping pace with the rate at which the complexity of weapons system electronics is increasing, so that the electronics subsystem reliability trend has been stationary or downward (Gates, et al., 1974).

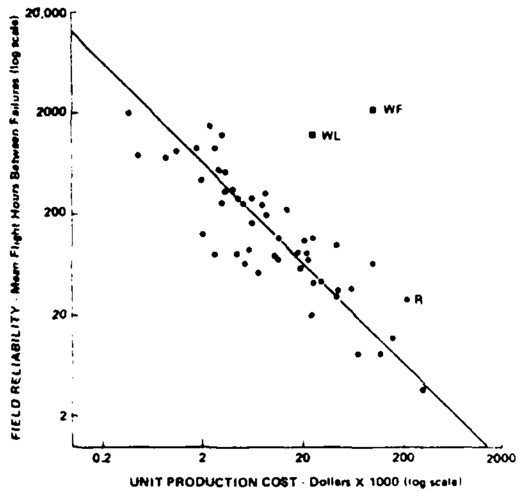

FIGURE 2. Field Reliability as a Function of Unit Production Cost. R, WL, and WF indicated special reliability program. (Adapted from Gates, et al., 1974)

If you accept that there is a direct relationship between system cost and weight, it will not surprise you that reliability also decreases as weight increases. Figure 3 shows some data presented by the Naval Weapons Engineering Support Activity (1978). It will be interesting to see how the F-18 reliability actually delivered operationally compares with that promised by the contract requirement. If you would like to try predicting which of the two points plotted for the F-18 is likely to come closer to what really happens, Figure 4 may help you. Figure 4 shows promised and actually achieved reliability for several tactical airborne radars, and in every case the operationally delivered mean-time-between-failures did not live up to the specification (Pyatt, 1972).

The point of emphasizing the reliability problems with complex systems is the obvious implication for overall support costs, and maintenance in particular. When a complex system breaks down, maintenance comes into play and the longer the maintenance time required, the less time the system is available to perform its intended function. Readiness thus depends directly on the maintenance function. The sophistication of systems has required sophisticated approaches to maintenance, such as the use of Automatic Test Equipment (ATE).

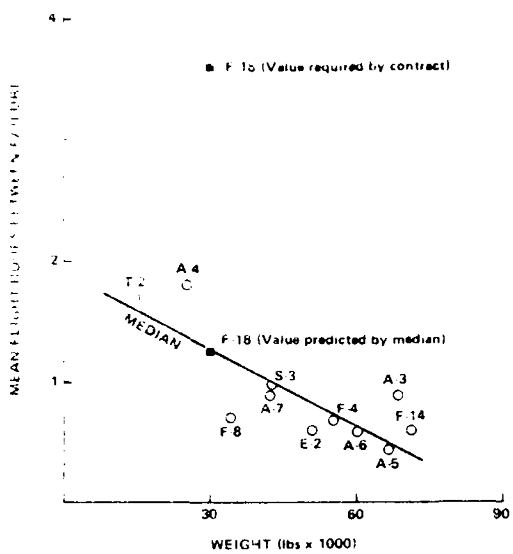

FIGURE 3. Field Reliability of Indicated Aircraft as a Function of Weight. (Adapted from A Prediction of Aviation Logistics Requirements, NAVWESA, 1978)

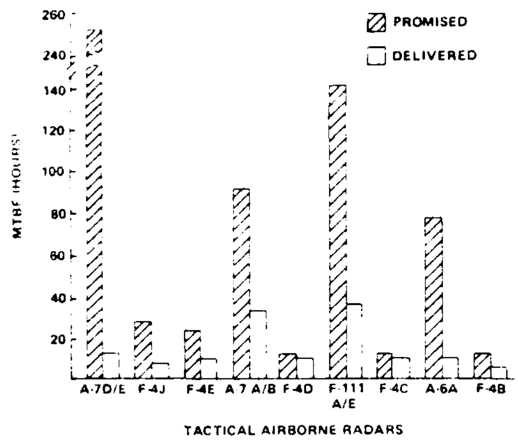

FIGURE 4. Reliability promised in the specifications and operational reliability actually delivered for several tactical airborne radar systems. (Adapted from Pyatt, 1972)

The use of ATE has resulted in savings in costs, space, and resources, but at the expense of an upgrading in technician training (King and Duva, 1978). A notable instance of increased need for sophisticated maintenance personnel as a result of ATE use is given by the Versatile Avionics Shop Test (VAST) system. VAST is a large and complex general-purpose, computer-controlled test system used by the intermediate and depot level maintenance activities to test and fault isolate avionics equipment from several Naval aircraft. Studies comparing avionic support by VAST and peculiar ground support equipment ... avionics have shown that VAST reduces maintenance ... sonnel time and elapsed maintenance time (Myles ...). However, original predictions about training fo... VAST have not been realized. Myles (1978) described the prob- lems succinctly (P. 21):

> The original concept of VAST envisioned ... use of an operator with minimal training. This ... cept has been shown lacking because it a... situation in which the program will be perfe... machine will always operate proper..., and doc... tation associated with the testing process will always be up-to-date and correct. Experience has show... all of these factors seldom prevail in spite of the ... stringent efforts. . .The assumptions originally made concerning the VAST maintenance technician ... suffered from the same inaccuracies as with the ... ator. . .this technician required more training and ex- perience to effectively troubleshoot the com... VAST system.

VAST training was expanded in response to the proble... Myles described. More recently, VAST training was mod- ified again, to include a course to produce a new kind ... VAST technician, the Test Program Set Analyst, and ... expand still further the maintenance courses (Van ... 1978). The point is that even though the support hardwa... for complex and sophisticated systems may match those systems in sophistication, maintenance still is ultimate... dependent on people.

My argument so far is simply that defense readiness depends upon the availability of maintenance perso... who can return a malfunctioning system to the operational state. There is nothing really new in such an argument: th... point was forcefully made more than fifteen years ago b... Morgan, Cook, Chapanis, and Lund (1963, P. 374):

> Equipment that requires skill levels higher tha... those that can be made available cannot be maint... ed successfully. In fact if the maintenance-skill le... required is much in excess of that available th... equipment can be a liability rather than an asse...

The proliferation of increasingly sophisticated equipm... is pushing us toward ever higher skill-level requirements which can only have an adverse impact on defense rea... iness.

The availability of maintenance personnel who ca... return a malfunctioning system to the operational stat... may be thought of as maintenance technician readiness. The readiness of a technician to perform as intended w... certainly depend upon several factors, including long term ones such as the quality of personnel available for mainte- nance and support activities, and short term ones such as moment-to-moment fluctuations in the technician's atten- tion. Among the most important determiners of technicia... readiness are the subjects of this conference, training and aiding. Some of the papers presented here sound the theme

that training is the critical element, whereas others argue that with adequate aiding to provide the technician with the needed information, training may be de-emphasized. I look forward to finding out whether an approach combining the two may be the solution. Regardless, improved defense readiness is ultimately dependent on the readiness of technicians, and that in turn means personnel who have the information they need when they need it, and the skill to apply it.

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BIOGRAPHICAL SKETCH

Dr. Paul E. Van Hemel graduated from Hobart College in 1965 with the B.S. degree in Psychology. He continued studies in Experimental Psychology at the Johns Hopkins University, earning the M.A. in 1967 and the Ph.D. in 1970. He subsequently taught at the University of Maine, Portland-Gorham, and at Franklin and Marshall College in Lancaster, Pennsylvania, authoring several articles in professional psychology journals before joining the Human Factors Laboratory, Naval Training Equipment Center, Orlando, Florida in 1977.

MAINTENANCE TRAINER VS FLIGHT TRAINER PROCUREMENT: SOME STRIKING DISSIMILARITIES

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ABSTRACT

This paper compares the procurement of maintenance and flight trainers in the Navy and reports preliminary results evaluating the use of a maintenance trainer in an advanced technician training course. Procurement of flight trainers is a carefully controlled procedure that begins early in aircraft acquisition processes and is focused on developing the skills needed to operate a new or modified aircraft. But the Navy does not typically procure maintenance trainers. Usually, technician training is considered late in the RDT&E acquisition process and not at all during the Modification acquisition proccess. Results of pilot testing on an experimental technical training course indicate that substantial dollar savings could be obtained from applying a coherent, disciplined approach to course design. The purpose of this paper is to focus attention on the benefits that could be obtained by applying Maintenance Instructional Technology (MIT) to the procurement of technician training systems.

INTRODUCTION

The Department of Defense has emphasized using flight simulation training devices for training pilots and other aircrew personnel (Cream, Eggemeier, and Klein, 1978). However, the use of maintenance training simulation devices for training technicians is not emphasized. In fact, the use of actual equipments for technician training is encouraged. As a result, the services are not taking advantage of known methods for increasing training effectiveness and reducing training costs.

The prime cost of military system ownership is the maintenance personnel subsystem. There are approximately 240,000 full time technicians in each service, and it costs some $5 billion per year to have these technicians on the job. With regard to training, about one-fourth of these technicians are new to the services each year and it costs approximately $1.2 billion per year per service to support these technicians while they are being trained (Shriver, 1975). The services simply cannot afford to continue ignoring proven methods for increasing technican training effectiveness and reducing training costs.

This paper compares the procurement of flight and maintenance trainers in the Navy and reports preliminary results evaluating the use of a maintenance trainer in an advanced technician training course. The purpose of the paper is to focus attention on the benefits that could be obtained by the services from applying Maintenance Instructional Technology (MIT) to the procurement of technician training systems.

FLIGHT AND MAINTENANCE TRAINER PROCUREMENT

Relative Number of Navy Flight and Maintenance Trainers

Trainer devices supported by NTEC are described in the Directory of Naval Training Devices. Over 70% of the roughly 300 trainer devices described in this Directory (Sections 1, 2, and 4) support aircrew training, 25% support other operator training, and less than 5% are used exclusively to support technician training. Of those trainers used to support technician training, most are two-dimensional displays of system schematics, or "cutaway" models of system equipments. Very few provide for "hands-on" practice of technician tasks and these almost exclusively involve stimulation of actual system equipments.

Flight Trainer Procurement

During the procurement of new or modified aircraft, there are stated requirements for the application of instructional technology (MIL-T-29053, 1977). From the beginning, flight training requirements are based on analyses of pilot tasks that are required to operate the new aircraft under a variety of mission conditions. Pilot aids, designed to unburden the pilot during the performance of some of these tasks, are systematically identified. For remaining tasks, knowledge and skill learning objectives are specifically identified and sequenced in a coordinated, comprehensive fashion. A broad, integrated range of media is used to achieve these learning objectives. Lectures and

individualized instruction are supported by audio-visual and text materials to achieve knowledge objectives. These materials are designed and developed by contractors who are experienced in the development of training programs. For skill learning objectives, a family of flight trainers is acquired. This group of devices permits progressive development of pilot skills. That is, the pilot begins with fundamental, generalizable skills and progresses to complex, system-specific skills, including team skills in some cases. Finally, since procurement of flight trainer devices is initiated very early in the acquisition process, they are delivered, and can be evaulated, at the same time the newly developed aircraft undergoes Operational Test and Evaluation (OPNAVINST, 1974, Feuge and Lankford, 1976).

All of these procurement practices assure safe, effective, and efficient pilot training. Trained pilots are available when they are needed to fly newly developed or modified aircraft, because experienced pilots are transitioned to the new aircraft while initial training is provided to novice pilots. And, once developed, pilot skills are not allowed to deteriorate through disuse, because refresher training is provided as part of the flight training program design.

In summary, procurement of flight trainers is a carefully controlled process that begins early in aircraft acquisition processes and is focused on developing the skills needed to operate a new or modified aircraft. Flight trainers are considered an essential part of the overall flight training system. The procurement of flight training systems is supported by *Directives, Instructions, and MIL* Standards.

Maintenance Trainer Procurement

During the acquisition of a new or modified weapon system, there are no requirements to separately address technician training. Technician training is considered along with operator training in existing acquisition processes.

Typically, technician training requirements are not identified in the RDT&E acquisition process until the weapon system is in the Full-Scale Development phase. But at this point, it is too late to make trade-off decisions affecting technician training efficiency and effectiveness since over 95% of the system life-cycle costs are committed (HARDMAN, 1977) and, for Modification acquisition, technician training requirements are usually ignored until deficiencies in maintenance performance are recognized. This realization occurs after the modifications have been implemented and the system is not properly maintained.

Identification of technician training requirements for new weapon systems is not usually based on analyses of tasks. Rather, technician training requirements are based on subjective assessments of differences between the new system and existing, similar systems. If the system under development is judged to be significantly different from existing systems, new training requirements may be identified. Otherwise, existing technician training courses are presumed to be adequate. These technician training requirements, along with operator training requirements, are documented in the Navy Training Plan (OPNAVINST, 1975). The costs for satisfying unique training requirements must be budgeted for by the Program Manager of the development.

For modified weapon systems, technician training requirements are identified by technician-instructors, who have received little or no training in the use of instructional technology methods. These technician-instructors are concerned with altering existing curricula rather than conducting a task analysis of the modified system. As a result, inadequacies in existing curricula are not usually addressed.

Once technician training requirements are identified, a restricted range of media is generally used to satisfy these requirements. Typically, technician training courses depend on lectures supported by technical manuals. For new weapon systems, these lectures are developed by Navy technician-instructors who have been introduced to the new system by the prime contractor (OPNAVINST, 1973). Actual equipments are frequently used by the contractor to train the initial group of technician-instructors. The contractor's usual inexperience in training program development also results in initial technician-instructor training materials that are prepared largely by design engineers. Finally, the prime contractor is often funded to support the new system until the Navy can maintain it. Therefore, it is really not advantageous to the contractor to provide comprehensive training program development. These materials require more sophisticated reading skills than most student technicians possess. Further, little concern for head/book trade-off issues (Joyce, 1975) is reflected in these materials.

As a result, initial technician training courses are not usually comprehensive nor are they supported by carefully selected media.

Maintenance trainer devices used for developing technician skills have only recently been considered by the Navy (Brock, 1978, a). Where the requirement for practicing technician skills is recognized, actual equipments are frequently used. In fact, it is Navy policy to provide actual equipments for training purposes (OPNAVINST, 1971). Actual equipments are used even when the cost of such equipments far exceed the cost of maintenance trainers that could be designed for effective technician training.

The cost benefits of using maintenance trainers compared to actual equipments are well documented. For instance, Daniels and Cronin (1975) estimate a $2.4 million dollar savings in the acquisition cost of a simulator over one suite of an actual electronics system. A comparison of the life cycle costs of the two systems resulted in an additional savings of $1.3 million. In another study, Miller and Rockway (1975) found that the cost of two sets of actual equipment exceeded $980,000, while two complete simulation packets were available for slightly under $170,000.

In addition, the use of actual equipments for technician training has some serious deficiencies. These equipments cannot be programmed for a variety of faults, they may be hazardous to users, they do not provide technician performance measures, and they are not "student-proof." As a result, it is impossible to design a logical progression of skill development, student practice must be monitored constantly to avoid injury and provide subjective assessments of performance, and substantial resources are required to maintain the equipments used by students. Additionally, it is often difficult to update these equipments to reflect alterations to systems in the fleet. These equipments are not usually available for training purposes until long after the newly developed system has been operationally deployed and, by that time, training curricula have been developed without the equipments. In these cases, use of equipments for skill development is "tacked on" at the end of the course.

Maintenance team skills are not addressed in most technician training courses because for the most part, technician training courses are rating specific. When two or more technicians with different ratings are required to perform maintenance tasks together, they must learn team skills on the job. Maintenance trainers that permit the development of the team skills in a controlled training situation are rarely, if ever, considered.

Technician training programs are developed to provide initial training, but transition and refresher training are usually not considered at the time of course development. Presently, for example, a Boiler Technician who has been assigned to a 600 psi ship may be assigned to a 1200 psi ship with no transition training at all.

In summary, the Navy does not typically procure maintenance trainers. Usually, technician training is considered late in the RDT&E acquisition process and not at all during the Modification acquisition process. Technician training relies heavily on lectures supported by technical manuals. Where the need for skill development is recognized, actual equipments are usually used. The procurement of technician training systems is not supported by Directives, Instructions, or MIL Standards that separately address technical training.

MAINTENANCE TRAINER EVALUATION

Background

Automatic Boiler Control (ABC) systems are used to control processes that produce the steam needed to operate ship propulsion, electrical generation, and auxiliary equipments aboard ship. Proper functioning of the ABC systems is essential for accomplishing the ship's mission. However, the Director of the Steam Propulsion Improvement Project recently reported, "Many ships have been unable to satisfactorily accomplish boiler flexibility tests without requesting outside assistance. A contributing factor to this situation is the general lack of knowledge and fault analysis capability of ABC maintenance technicians" (Greer, 1978). A research project was undertaken to explore ways of correcting this situation for Hagan ABC technicians.

Official Course Description

The official course used to train Hagan ABC maintenance technicians is a stand-up lecture, limited media course. Groups of about 15 students progress through the course during a five week period. Students practice component disassembly, inspection, reassembly, and calibration tasks using actual components, following demonstrations performed by instructors. In addition, they practice diagnosing the causes of several casualty conditions inserted by an instructor using a Pneumatic Maintenance Simulator (Shown in Figure 1). This simulator consists of actual ABC system components that are stimulated by

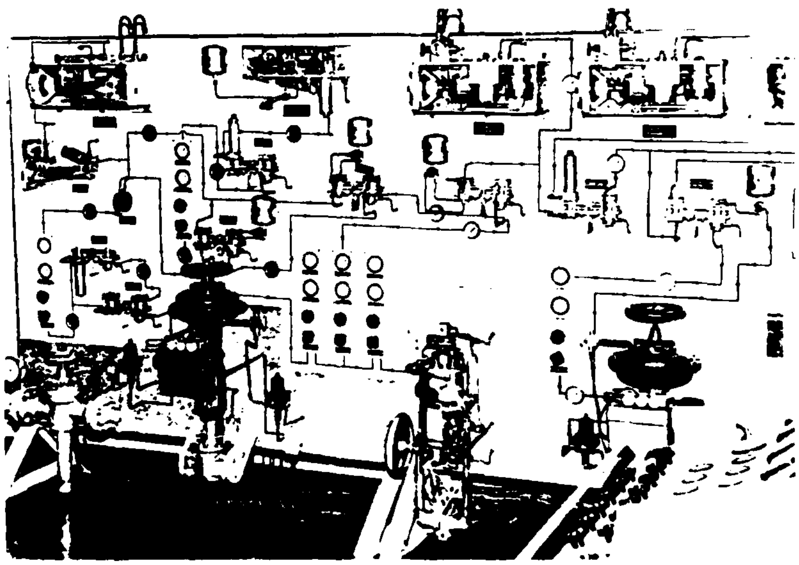

FIGURE 1. Pneumatic Maintenance Simulator

pneumatic and electrical signals. The causes of casualty conditions are diagnosed from symptoms displayed on gauges contained in a Boiler Console replica. An instructor must be present to provide feedback regarding the cause of the casualty condition he inserted. The acquisition cost of the two Pneumatic Maintenance Simulators used in this course is reported to be $360,000 and the annual maintenance cost is reported to be $35,000 to $50,000 (Swezey, 1978).

Experimental Course Description

An experimental course was developed to train Hagan ABC system maintenance technicians. This course uses an individualized, self-paced, mixed-media approach. Students achieve knowledge learning objectives using text and audio-visual programs. Skill learning objectives are achieved using actual components and a maintenance trainer, called a Fault Identification Simulator (FIS). A FIS is shown in Figure 2.

an incorrect diagnosis. If two incorrect "repair" actions are taken, the FIS advises the student to contact his Learning Center Supervisor. Finally a backlighted schematic of the ABC system is provided to help students conceptualize system dynamics during troubleshooting skill development. The acquisition cost of three FIS devices is reported to be $111,000, and the annual maintenance cost is reported to be less than $5,000 (Swezey, 1978).

Preliminary Evaluation Results

The experimental course was pilot tested at the Fleet Training Center, San Diego. Student completion times are shown in Figure 3. This figure shows that the 16 students in the course completed the course, on the average, in approximately two-and-a-half weeks. The slowest completion time was just over three weeks, and the fastest completion time was just under two weeks. These completion times were achieved even though training objectives associated with troubleshooting skill development were added to

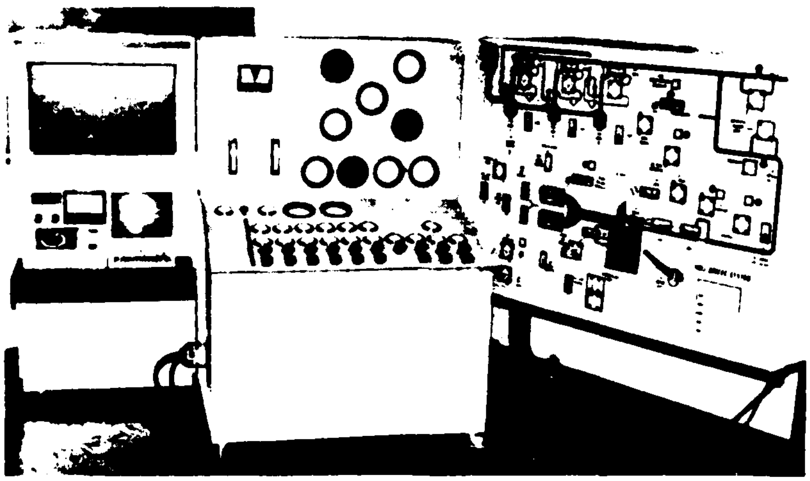

FIGURE 2. Fault Identification Simulator (FIS)

Students practice component disassembly, inspection, reassembly, and calibration tasks using actual components along with Job Sheets describing how to perform step-by-step procedures. Students may take these Job Sheets with them when they graduate from the course and, thus, they become performance aids.

Three FIS devices were provided in the experimental course. Each FIS is capable of displaying the symptoms of 23 different fault conditions on a Boiler Console replica. All fault conditions resulting from a single component failure in the actual system can be represented in a FIS. In addition, students can interrogate the FIS and receive the information about system component measures, that they would obtain in the actual system. Students can "repair" any of the system components and observe the consequences of their actions. If they elect to "repair" a component that is not faulty, the FIS immediately indicates

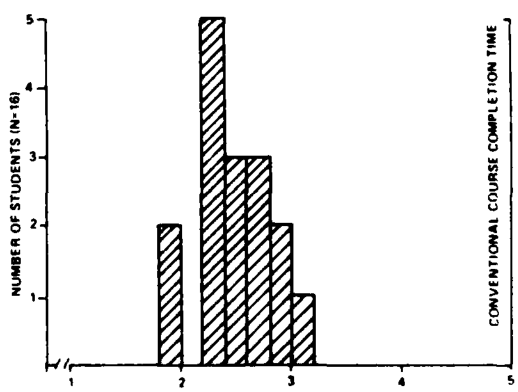

FIGURE 3. Student Course Completion Times

those contained in the official course. Contrasted to the conventional course completion time of five weeks, these figures represent a considerable increase in efficiency.

If the experimental course were officially implemented, and students were given flexible detailing to the school, a minimum savings of 180 man weeks, almost three-and-a-half man years, could be realized. The yearly pay of a typical Hagan technician is $14,819. Therefore, the savings of three-and-a-half man years is nearly $52,000 (Brock, 1978,b). Since the same course is also taught at the Fleet Training Center, Norfolk, over $100,000 per year could be saved in technician pay by adopting the experimental course and providing flexible detailing to the schools.

In addition, since the FIS uses a progammable microcomputer, fault condition symptoms can be economically changed to reflect modifications to the Hagan ABC system. This is important because experience suggests that SHIPALTS which should be incorporated in maintenance trainers occur about once every two years. Presently, the Pneumatic Maintenance Simulators used in the official course will be modified to reflect recent SHIPALTS. The cost of making these changes for the four devices in San Diego and Norfolk is estimated to be $100,000. The cost of modifying the FIS programs is estimated to be $20,000.

Total savings to the Navy, if a technician course like the experimental Hagan ABC Maintenance Course were adopted, are dramatic. For this one course, over a ten year period, about $1 million could be saved in technician pay, $600,000 could be saved in maintenance cost, and $400,000 could be saved in making modifications to the maintenance trainers, for a total savings of $2 million.

More importantly, however, technicians would be given an opportunity to develop those troubleshooting skills needed to isolate faults aboard ship. A simulation maintenance trainer can be used to represent a comprehensive range of fault conditions and provide immediate knowledge of results as well as student performance measures. As a result, the fault analysis capability of graduate technicians is upgraded. This kind of training has a direct and obvious impact on system availability.

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BIOGRAPHICAL SKETCH

Dr. Robert G. Kinkade is Director of the Essex Corporation San Diego Facilitiy. He is responsible for the overall scientific, and management direction provided during the conduct of training research, training program development, and media production. He has recently been involved in performing research on maintenance instructional technology, developing shore-based and on-board training programs for engineering propulsion maintenance technicians. Dr. Kinkade has applied human factors and instructional technology to a variety of systems over the past twenty years. He received his Ph.D. from Ohio State University in 1960 and his M.A. and B.A. from the University of Missouri.

IMPROVED OJT FOR DOD

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ABSTRACT

A set of guidelines for maintenance OJT to improve its effectiveness. Effective OJT is essential to mission support; improved OJT effectiveness is needed in many specialties because of the greater demands placed on maintenance personnel by advanced technology and because of the greater diversity of equipment and duty stations in today's military environment. Deficiencies in current OJT programs arise from the nature of the working environment and from disincentives that encourage only superficial adherence to the services' policies for OJT. The content, resources, and management of preferred approaches to OJT are described. In particular, formalized conduct of OJT by separate units within the operating commands is advocated. Successful OJT programs that have followed this approach are described as evidence of their practicality and utility.

INTRODUCTION

In peacetime, training is one of the main purposes for the conduct of military operations. Although the resources required to support operational training activities are not budgeted for training, as such, clearly their cost is far greater than the cost of formal training. Moreover, the training given in operating units is essential for maintaining readiness. In many specialties readiness can be more significantly improved by improving the effectiveness of operational training than by improving training in technical schools.

Effective OJT also alleviates problems of local management by assuring supervisors that people are capable of performing tasks for which they have been "signed off," thereby supplying identifiable groups of competent workers.

The portion of OJT that qualifies people to perform tasks is the link between school training and performance on the job. Therefore, improvements in this aspect of OJT can also lead to increased efficiency in school training by better identifying its content or by decreasing the need for school training in specific tasks.

The effectiveness of OJT for task performance has become more important in recent years for several reasons. One is the increased technological sophistication of military equipment and systems, which places greater demands on maintenance personnel. Even systems that have been designed to minimize demands for maintenance in the field often require special skills that are inadequately taught in an introductory course. [1] Another reason is the diversity and proliferation of systems in the field. For example, in the division forces of the Army there are now about 0.71 items of major equipment for every soldier.

Although school training can give people a general preparation to cope with this environment, it is difficult for school training to qualify the graduate for job performance. For one thing, actual job conditions often are not duplicated in school training. Moreover, so many variations in the working environment are possible that attempts to duplicate all possibilities would make training excessively expensive.

McLarty, an instructor in the Armor school at Fort Knox, graphically describes the situation for the turret mechanic specialty:

> (In formal training). . .the student learns his skill within a classroom and laboratory environment. . . . All manuals, tools, and test equipment required to diagnose and repair faults are readily available. A skilled instructor, along with a group of peers, is available to render advice and assistance,. . . In the field,

[1] See, for example, Carpenter-Huffman and Rostker, 1975.

the turret mechanic finds that maintenance, instead of being the primary focus of each day's activities, is now ancillary to a multitude of missions . . . . Turret trainers and reasonably comfortable laboratories have been replaced by functioning combat vehicles with myriads of faults and shortcomings; and a motor pool or trains area that most likely is exposed to whatever Mother Nature has to offer. . . . He may often be required to work alone, or with only tank crewmembers to detect and correct malfunctions. He may well find that his unit is short tools and test equipment that were readily available in school. (McLarty, 1978, p. 9).

Beyond what may be relatively minor variations in local conditions, we have already mentioned the diversity of tasks with which the service person may be faced in the field, even within a single specialty. In the Army, for example,

> A soldier in MOS 11B1 may serve in anyone of 33 jobs (duty stations) when he leaves his one-station unit training . . . and goes to a unit . . . . Before he is sent to his unit, the 11B1 soldier is currently trained in only five jobs . . . These are among the highest density jobs, so the odds are he will wind up in one of them. But, what if he does not? Well, he must then be trained on the job by his supervisor.
>
> . . .
>
> In other MOS the problem is one of difference in equipment as compared to number of jobs. An artilleryman in MOS 13B, for example, may work with any one of five cannon weapons systems when he completes his entry training . . . he is trained (only) on the most prevalent, the self-propelled 155 Howitzer, M109E1. (Department of the Army, pp. 3-1 and 3-2).

Similarly, the Air Force Ground Radio Equipment Maintenance career field (304X4) encompasses 4 distinct jobs for first-term airmen.

Although this problem may partly be resolved by tailoring training to the job of first assignment (resulting in several different initial courses within the same specialty), the problem remains of insuring that persons have the needed skills when they move about within the specialty (or if they are initially misassigned) and when they upgrade.

In sum, initial training in formal schools will rarely be able fully to qualify maintenance personnel for their first jobs because job performance is more or less idiosyncratic to the work environment. In addition, OJT will always be needed for upgrade training, to refresh skills in important tasks that are rarely or never performed in the normal work situation, and to introduce new equipment or procedures.

People in the field often view properly conducted OJT as the most effective of all training the service has given them. Although this view may partly be due to myopia (since their OJT is the freshest in their memories), it is true that OJT teaches job performance by guided practice, generally considered the most effective method of teaching skills. [1] In addition, OJT is largely generated by immediate maintenance needs, which helps insure its relevance.

In what follows I shall present evidence of present problems in OJT and discuss their underlying causes. These problems are not found in all maintenance specialties, but often arise in those in which maintenance personnel work under difficult conditions or are under production pressure. Next, I shall propose a general approach to resolving these problems and describe instances in which application of similar approaches has improved OJT. My intent is to urge fundamental changes in the management of OJT and to present some guidelines for improvements in OJT for maintenance specialties in each service. I shall not deal with aspects of OJT such as correspondence courses that may support, but do not directly teach, job performance.

DEFICIENCES IN CURRENT OJT

Several years ago the Tactical Air Command (TAC) administered a questionnaire at all operating bases where advanced avionics were maintained, as part of an effort to improve management and training of avionics maintenance personnel. [2] This questionnaire included open-ended questions eliciting respondents' reactions to their OJT. Many assessed OJT as having been the most useful of all the training they had received. Even OJT-enthusiasts, however, often noted deficiencies in the training or suggested improvements.

A recent Rand survey of personnel skilled in maintenance of Army land vehicles uncovered similar deficiencies. [3] Although I cite specific sources of evidence, however, I believe the deficiencies observed arise to a greater or lesser extent in many maintenance OJT situation.

The first set of problems is caused by the work situation and the way the trainee is managed within it. Scheduled and unscheduled maintenance tasks arise in response to the needs of the operating unit, not in response to train-

[1] For a description of respondents' comments on <u>formal</u> training, see Carpenter-Huffman and Rostker, 1975.

[2] See, for example, Air Training Command, 1968 and 1970; Pieper, et. al., 1970; Taylor, et. al., 1972; Weingarten, et. al., 1972.

[3] Documentation of the survey by Harz, part of the Rand Land Vehicle Maintenance Study for the Defense Advanced Research Projects Agency (DARPA), has not been released. The results, however, have been briefed to the Army as well as to DARPA.

ing requirements. Thus, the trainee may have more than enough chances to learn one task, whereas he may never be exposed to other tasks equally necessary for journeyman qualification. In the words of one airman: The OJT program was not adequate because only certain areas of maintenance are consistently being worked on at this particular (air) base and other maintenance in other systems is rare or non-existent.

The vagaries of the work situation are exacerbated by the management of trainees. Trainee time may largely be absorbed by additional on-site training unrelated to the job (such as driver education), cleanup and other routine details, and acting as a go-fer. Many of the respondents to the TAC questionnaire complained about the amount of time required for "ridiculous squadron and barracks details" or about not being allowed to work on the aircraft. Although some of these complaints may have represented normal griping, many of them were voiced by more senior personnel who were not at the time burdened with "ridiculous" details.

Another set of problems arises from failure to enhance the work situation with resources needed specifically for training. The most important of these is a person who both knows and can teach the job (a trainer). Sheer unavailability of trainers was noted by many respondents to the TAC questionnaire. TAC feels its problem has worsened during the last few years in this regard because of a marked decrease in the authorized ratio of skilled to unskilled enlisted personnel. In 1973, TAC had for each person with grade E-1 through E-3, 1.76 people with grade E-4 through E-6. The corresponding ratio in 1978 was l.04.

The Army faces similar difficulties. For example, McLarty noted that in the turret mechanic MOS:

> The fact is that we haven't really had a qualified turret mechanic supervisor in most units. This has been largely due to the fact that the organizational turret mechanic could only progress through grade E5 in his primary MOS . . . . (McLarty, 1978, p. 10).

Even when the unit has people qualified to train others, these people may be forced by production demands to slight their training responsibilities. This is most likely to happen in specialties closely tied to mission operations, such as flight line aircraft maintenance.

In most instances, a person who has been designated as a trainer knows enough about the job to perform it. In some cases, however, particularly where relatively new equipment is involved, even the designated trainer is inadequately skilled, either because he has been pushed up the skill ladder without comprehensive OJT, because he has not had the chance to become familiar with the equipment, or because the specialty itself has newly been created. One Air Force staff sergeant stated flatly that:

> The OJT program is worthless. OJT trainers did not know enough about equipment to be trainers.

Lack of trainers with sufficient job performance skills is not limited to the most technologically advanced specialties, however. The Rand survey of Army land vehicle maintenance also noted that supervisors who were expected to train others needed much more thorough experience in each of the different maintenance tasks--repair, ordering parts, and completing forms, for example.

Finally, even when enough skilled personnel are available to provide the training required, persons assigned as trainers may be poor instructors. It is unlikely that a maintenance journeyman has been trained to teach, nor is there reason to believe that he has natural aptitude as a teacher. In addition, the over-riding incentives for most trainers are to do the work, not to train someone else to do it. <u>The most common single complaint about OJT on the TAC questionnaire was that those assigned as trainers were inadequate as teachers.</u>

Normal operating equipment may also be inadequate for the training situation. For example, on the flight line trainers often need such minor items as additional headsets for instructing trainees. Thus, in addition to deficiencies in the availability or quality of instructors, problems may also arise from the lack of supplies or equipment needed specifically for training. Training equipment may be particularly useful for teaching sophisticated skills (such as troubleshooting) or performance of dangerous tasks.

CAUSES OF OJT DEFICIENCIES

Each of the services has established procedures for the conduct of OJT which, if they could be fully implemented, would help provide adequate training. In fact, respondents to both the TAC questionnaire and the Rand questionnaire urged that the OJT programs that exist "on paper" be put into effect to remedy training problems.

Mere exhortation to implement existing policy is unlikely to effect more than superficial, passing change, however, for two reasons. First, commanders are not immediately rewarded for the quality of their maintenance activities, let alone their maintenance OJT programs. Instead, they and those they command are penalized if documentation of progress in OJT does not conform to the schedule set for it. Second, as discussed above, for many specialties the normal work environment, in which OJT is to be conducted, is not conducive to effective training.

Let me expand briefly upon the problem of disincentives. The relative remoteness of maintenance activities from primary combat missions leads to widely varying and often inadequate emphasis on maintenance by managers and supervisors. In Army wheeled vehicle maintenance, Harz found that maintenance officers and NCOs are often lacking practical experience in their field. Harz also found that pressures to "come in as Category I" on the Operational Readiness report often destroy the validity and usefulness of vehicle preventive maintenance and operational readiness records.

On the other hand, since progress in OJT is tied to the promotion system, supervisors are under pressure to certify a person's competence whether or not the certification is warranted. For example, in the Air Force the supervisor designates for each person the skills necessary his qualification, and one new 5-level may have mastered many job-related tasks while another may have mastered few or none. Thus, it is not too surprising to read the comments of one airman that:

> After 6 months you're given a 5-level whether you want one or not. Your abilities on the aircraft don't matter as long as you spent 6 months on this base. Therefore, there are many 5-levels who don't know anything more about the aircraft than the 3-levels assigned to them (as trainees).

Many other respondents to the TAC questionnaire urged that OJT cease being dominated by requirements for skill upgrading.

To cope with a similar problem, the Army is replacing the "MOS tests" with Skill Qualifying Tests (SQTs) to verify an individual's present skill level and to qualify him for award of the next higher skill level.

> Soldiers scoring 80 percent or above on the SQT will form a pool of soldiers who are qualified for award of the next higher skill level. Promotion quotas will be filled from that group first using additional criteria. . . (Department of the Army, 1 April 1977, p. 4-5).

Thus, scores on the SQTs may provide sorely needed measures of OJT effectiveness.

A GENERAL SOLUTION

The approach I advocate is a formalization of the task training portion of OJT within the operating unit. Below I describe the content, resources, and management needed to improve OJT in those specialties in which it is currently deficient.

Training Content

All apprentices should master a set of skills identified by supervisors who are both concerned with and informed about the current job. These are the skills they feel are needed by a competent journeyman. This does not mean that all training content should be technical in nature, however. Other skills needed for adequate job performance, such as work planning, should also be taught. (U. S. Department of Labor, p. 20).

On the other hand, often when training is given in the normal work environment, the trainer fails to give adequate explanations of how or why a particular procedure is used; that is, whereas formal training may overemphasize abstract principles, OJT may slight them. Some understanding of why a procedure is followed not only helps the trainee cope with novel situations but also improves motivation. Probably it is most efficient to determine how much theoretical background is useful or necessary to support an individual's performance of a given task during instruction of that individual on that task.

Unless all training is done in the work environment, special provisions are needed to keep the content of training relevant to the job. This, primarily a management problem, is discussed further below.

Training Resources

As already discussed, maintenance personnel are not usually expert instructors, although many of them may empathize with the student and communicate well with him, as a good instructor must do. But a good instructor also must be able to schedule teaching situations to build on what the trainee already knows, arrange problems to highlight new learning and to provide practice for skills already learned, and adjust the pace of training to the trainee's needs and motivation. Of course, a good instructor knows the subject matter well enough to teach it, although he need not be the most skilled maintenance person in his specialty.

As with any skill, both aptitude and training are needed to produce a good instructor. Ideally, instructors should receive both initial training and OJT in how to instruct. (U. S. Department of Labor, p. 22).

At least part of task training must be conducted on actual equipment in a close approximation of the working environment. This is particularly important (and difficult) for maintenance that must be performed under difficult conditions, such as out of doors in bad weather or on equipment that is hard to get to. Showing trainees how to work under such conditions is an essential part of training.

Since operational equipment may not present sufficient opportunities for learning particular tasks, some task training may need to be conducted outside of normal operations. Preventive maintenance can sometimes be taught on equipment that is temporarily not needed (on the weekends, for example) or that is out of operation for some reason that will not interfere with the training. Each of these situations introduces problems of scheduling, but a determined instructor can often work around them.

Bonafide malfunctions should also be used to teach skills in unscheduled maintenance. Although this again puts the teaching at the mercy of production schedules, more advanced trainees working in realistic situations will learn about production pressure as they practice job performance. Before they reach this point, however, they need to have mastered tasks performance skills in structured training experiences.

Maintenance simulators, just now coming into use, may have application in this area; I'm sure their many advantages will be fully dealt with in the course of this conference. I would like to make two points in this paper--1) the utility of maintenance simulators should be examined for OJT as well as for school training, and 2)

because the trainee needs to learn to do his job in the working environment, simulators should not carry the entire burden of task training.

Similarly, facilities for OJT should include a mixture of realistic and training-oriented settings. Much of training could take place in a laboratory-like environment, but at least some of it should be conducted in an actual work setting or a reasonable facsimile of one. Realism is most important for specialties in which working conditions can be difficult, as mentioned earlier. "Field trips" should be scheduled both to observe on-going maintenance and to conduct it in situ. Field training sessions might be scheduled for off-days or in special areas to minimize disruption of regular maintenance. Instructors could "walk trainees through" a job from beginning to end and familiarize them with the activities and processes that generate maintenance tasks and that support them (e.g. maintenance control, supply points, and quality control). Duren has urged this type of training for flightline avionics maintenance. (Duren, 1976, p. 7).

Ideally, training should be given when the need for it arises in the work environment. This maximizes the trainee's opportunity to relate what he is learning to job performance and enhances his motivation to learn. As suggested earlier, however, production pressure can override training opportunities. In addition, normal work schedules may not give rise to training opportunities with the frequency needed. Thus, the timing of training needs to be closely linked to but not dominated by the work environment. One way to achieve such a mix is for the trainee to work part of the day and train part of the day.

Training Management

The first question is, what agency should administer the approach to task training I am advocating? Since I have emphasized the training process--scheduling of teaching sequences, competent instructors, equipment designed for training--, it might be argued that an organization whose major mission is training would be most appropriate.

In fact, service training organizations often establish temporary or permanent training units in the field; some of these are effective in bridging the gap between formal training and job performance. The Field Training Detachments (FTDs) of Air Training Command, for example, have several advantages over the technical schools because of their proximity to the workplace. FTD instructors are better able to maintain relevant course content because it is easier for them to visit the work centers to observe the latest techniques in job performance and to find out what shop supervisors need in the way of training. Often FTD instructors have had considerable experience in the unit and with the unit equipment and can draw from working expertise in their teaching. Training equipment used at the FTDs is more realistic than that at technical school, and the operating unit may make spares available to keep training equipment working or may allow FTD instructors to conduct training on equipment from the operating inventory.

Despite its proximity to the workplace, however, the FTD can also become isolated from the job. In avionics maintenance training, for example, FTD instructors and students rarely had access to actual aircraft and never used real malfunctions as opportunities for training. In fact, the physical demands of FTD duty, were considerably less than those of the flight line, and opportunities for self-direction were greater. Thus, people assigned to FTD usually wanted to remain there, and it took an aggressive and hard-working person who was willing to put in extra hours to maintain his practical expertise. It was not surprising that some FTD courses were strongly supported by the user others were condemned as irrelevant. (Carpenter-Huffman and Rostker, p. 76).

It is difficult to satisfy requirements for training relevance when instructors are ultimately responsible to a relatively remote organization whose major mission is training. If, however, the training is administered by persons responsible to those who employ their students (that is, by persons assigned to the operating command), incentives to maintain training relevance will be stronger. Although it may be difficult to keep such training from being captured by production needs, setting aside a separate activity for maintenance training will provide better protection than does the usual approach to OJT. Thus, I am advocating that the operating commands fulfill their current responsibilities for maintenance OJT by administering it formally within units separated from maintenance production.

The Navy's FRAMP (Fleet Readiness Aviation Maintenance Personnel) units appear to come close to meeting the specifications I have been discussing. Their mission is to train enlisted people to maintain specific aircraft. Naval policy dictates that maintenance training is to receive the same emphasis as pilot training. After formal schooling, practical maintenance training is conducted on fully operational FRAMP aircraft and supporting equipment dedicated to training in a separate facility. Practical training is provided by qualified petty officers within the appropriate maintenance specialties. This is followed by OJT within the operational unit.

The FRAMP may be the best solution to the Navy's OJT needs. [1] The Air Force and Army have a more complex problem because of the number and diversity of their units in the field. It will be complicated to determine how many maintenance training organizations are needed for each specialty or, possibly, for combinations of specialties dealing with different items of equipments or systems. The heterogeneity of the specialty, the number of people within it, its technical complexity, and the cost of

[1] Its major disadvantage is the poor approximation it provides to the operational environment.

different configurations would all have to be considered. Quite possibly, not every operating location would need such an organization; rather, some training might be concentrated at a few locations.

> Such a unit would ease the transition of the new assignee from formal training to work performance. It would also provide the continuation training needed for people changing duty stations or equipment, to assure continued job proficiency, to prepare people for upgrading, and to facilitate adjustment to changes in technology or procedures. (Department of Labor, p. 21).

I have already suggested the importance of evaluation in assuring the effectiveness of OJT. The Department of the Army SQT pamphlet supplies an excellent general description of procedures that should be used for such an evaluation. Should the separate unit for training administer such evaluations? The answer is probably "no" (except for interim evaluations), since that would put the unit in the position of evaluating its own product. Thus, it would be better for a different unit, say one associated with maintenance quality control, to administer definitive evaluations of OJT trainees.

It is unfortunate that upgrading is so closely tied to certification of OJT progress that progress is falsified to satisfy the upgrade schedule. Such falsification obviously does not help the commander assess the maintenance capabilities of his unit. If upgrading is as automatic as some have implied, occurring at the six-month point willy nilly, OJT could be decoupled from it with little ill effect. Certainly *patently undesirable persons* could still be denied promotion, and other ways could be found to reward outstanding performers.

EXAMPLES OF EFFECTIVE OJT PROGRAMS

The approach described above has been applied in the field and proven to be effective. I have already mentioned the FRAMP, which appear to be highly successful for the Navy. I am, however, most familiar with the Task Oriented Training (TOT) program instituted by TAC during 1975-1976, whose objective was to provide more effective practical training to TAC maintenance personnel.

> Task oriented training will teach a man the knowledge and skills necessary to perform specific tasks that are required in his current job assignment. This program will produce more capable graduates in a shorter amount of time who are able to perform the duties required by their supervisors. This will reduce the training burden on supervisors and complement the qualification requirements of the OJT practical channel. (Headquarters TAC, March 1975, p. 1).

Maintenance Training Management (MTM) was responsible for managing the TOT program, which required close interaction between wing personnel and the local FTD. For example, a Plan of Instruction was written jointly by MTM and FTD personnel. FTD personnel conducted all academic training and some practical training, with assistance by a TAC Instructor Augmentee, a job-qualified person assigned to the TOT course. The Augmentee conducted whatever practical training the FTD could not conduct and signed off maintenance actions taken on operational equipment, if sign-off was required and the FTD instructor was not qualified to do so. Final certification of the trainee's job proficiency remained the responsibility of shop management personnel.

The most significant feature of the TOT program was that TAC committed its own aircraft, equipment, and personnel to be used for hands-on training and that these commitments were included in formal course documentation. This commitment required TAC to:

> devise scheduling procedures to incorporate training course, aircraft, equipment and personnel requirements into monthly and weekly published utilization schedules. (Headquarters TAC, February 1975, p. 4).

Late in 1974, a number of TOT courses were evaluated in various ways. One, conducted by quality control personnel, was of the ability of TOT graduates to perform specific tasks. No discrepancies in task performance were noted for 35 3-level graduates at Seymour Johnson Air Force Base.

> It is significant to note that graduates of former FTD courses, which were not "task oriented," were not capable of being immediately administered MSEP (Maintenance Standardization and Evaluation Program) evaluations due to the fact that they were taught system orientation versus task orientation. (Minutes of January 21-23, 1975, Task Oriented Training Conference, p. 1).

Although TOT is no longer a separate TAC program, TAC has continued to press for formalized, practical training in maintenance specialties that have suffered from inadequate OJT in the past, especially those in which people work under production pressure. One significant result has been that many FTD courses are being designed fully to qualify maintenance personnel on a specified set of frequently performed tasks. (Headquarters TAC, 1978, pp. 3-1, 3-2).

McLarty describes a less structured approach that has been used for orienting new turret mechanics to their jobs.

> Regardless of how serious your turret problems may be, a few weeks spent in unit orientation and closely-supervised training will pay dividends in the long run. Some units, usually those who indicate the most satisfaction with their turrent mechanics, keep newly assigned turret mechanics at battalion level for a period of 2 to 3 weeks prior to assigning them to a line company. During this period they conduct formal . . . (OJT) which acquaints the men with unit standard operating procedures . . ., battalion supervisory personnel, provides additional training in those areas

currently comprising unit problem areas, reviews skills learned as much as 2 to 3 months earlier, and teaches those tasks not formally taught at the Armor School. This period of time also provides an important transition period during which the new turret mechanic adjusts to the differences between school and unit environment . . . . The battalion turret mechanic supervisor, Master Gunner, or senior turret mechanic is normally charged with supervising this training, and all can assist. (McLarty, p. 10).

Similar approaches were urged for Army land vehicle maintenance MOS currently suffering for lack of skilled maintenance personnel.

CONCLUSIONS

In this paper I have sketched an approach to maintenance OJT that will, I believe, relieve the deficiencies exhibited by many current programs, particularly those that are the responsibility of maintenance personnel working in a production environment. The approach I have described has been distilled not only from accepted principles of training but from the example of successful OJT programs in the field.

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BIOGRAPHICAL SKETCH

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DO AUTOMATED MAINTENANCE DEPENDENCY CHARTS MAKE PAPER-COVERED JPAs OBSOLETE?

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ABSTRACT

Job Performance Aids must provide exhaustive troubleshooting; solve all problems; be easy to use and to update; motivate the technician; help design; assist other aspects of Integrated Logistics; lightweight; and reduce human error in preparation.

It is impractical, from a volume standpoint alone, to implement the quantum of required information. At least one proven non-paper technique which is not ATE and not committed to one equipment has been validated by the Armed Services. "Only those bold enough to take up the challenge will benefit from the nutrition and vitality that ensues from this new form of non-paper, but simple, Job Performance Aid".

The foliage was a deep green, and the screeching of a birdlike creature awakened everything in its flight path. A ground-borne silhouette resembling a man, for lack of another name, appeared from within a protective cave. The man, standing on two limbs, yawned, looked up at the sky, disappeared back into the cave, and returned with some sort of a pointed stake in one hand and was followed by a smaller replica of himself, apparently an offspring. The two creatures awkwardly found their way to what appeared to be a swampy patch of ground, then on further to a clear body of water. From afar the larger man could be heard making sounds to which the smaller creature seemed to respond. The large man drove the pointed stake into the clear water in which he was standing, raised it from the water, and retrieved a sizeable fish. Then, the man gave the stake to his offspring to perform the same task while the larger man continuously uttered intonations. The youth responded by driving the stake into the water several times until he also served up a dangling fish. And so, this produced the first method of one creature instructing another how to obtain what would become its nourishment for survival. The instruction, as crude as it might have been, today would have been called a Job Performance Aid.

Our prehistoric ancestors used implements and instructions to help them perform tasks whether they be for pleasure or existence. This lasted for a few thousand years until man found methods of recording what he did so others could learn from the recordings. Thus, the preamble to man's quantum *jump into "modern time" recordings.* We now find ourselves in situations where mere recordings are not enough. Today, we have derived a SOURCE document of what has become an impediment rather than an aid in showing each other how to accomplish a new task. Remember, this SOURCE is not the teacher but is to be used to provide paper instructions detailing how a job is to be performed. For a while, most of us were overwhelmed and timid about using the SOURCE to provide instructions, and the silent but explicit outcry was "Let Harry do it!" Why? Because Harry was the handy person who always seemed to have that inate technical sense to solve technical problems without using the SOURCE and was able and willing to do our job for us. Do you remember what happened after World Wars I and II? Back we went to the necessities of doing jobs for ourselves, and with it came our ever present SOURCE to provide "Job Performance Aids". Into the Electronic Age of the 1950s and 1960s it became ever more of a necessity to perform jobs

with some sort of assistance. Electronic expertise was not so plentiful that a one-for-one training situation could occur, especially in the Military where most of the inroads in electronics were being made under the sponsorship of the U.S. Government. Yes, I suppose someone will relate the development of the transistor by Mr. Shockley, but remember, the Company from whom Mr. Shockley received his renumeration was very heavily supported by the U.S. Government. The ever watchful Federal Government provided funds to design and develop all kinds of electronic equipment. Today, we would normally pay for work by Mr. Shockley to an account which our financial personnel term "Independent Research and Development" (which is paid for to a large extent by Government Contracts).

By the late 1950s, our Armed Forces began to become more dependent upon the electronic wizardry of industry. Enter, Job Performance Aids again! Training and Maintenance had to be handled to a large extent by the Electronic Systems Contractors. In the middle to late 1950s, while working for one of these Government Contractors, I personally supervised about 160 degreed engineers who accomplished only one facet of a technical manual of maintenance instruction. That was the engineering writing. Illustrated Parts Breakdown Manuals, as well as multitudes of other manuals, were accomplished by another set of people all using different SOURCES. To continue the complication, illustrating, production and quality control were handled by even different groups. The total number of personnel involved in providing these "maintenance aids" was over 250. The annual dollar volume consumed each year amounted to approximately $6,000,000. Perhaps this does not seem to be a large number of personnel providing Job Performance Aids or even a large annual expenditure by today's standards. Today's larger companies are likely to employ 300 or more personnel producing Job Performance Aids with annual costs reaching the $15,000,000 mark. Is it any wonder that the volumes of technical manuals produced each year for our Armed Forces runs into the 100s of millions of dollars each year? Picture the year 1958 when an airborne radar set basically consisted of the antenna, power supply, transmitter, receiver, and synchronizer (rather than a computer) using tubes, as well as transistors, as the active elements having a total weight of about 80 pounds. This was my introduction into JOB PERFORMANCE AIDS printed on paper.

All publications were heavy on the theory and illustrations because, remember, the military technician has not seen this new breed of electronics. Troubleshooting malfunctions was only described on paper by the brave at heart who made assumptions of what might go wrong in the field for insertion into the paper manuals. Indeed, this reaction still exists today. When these paper Job Performance Aids failed to make the military technician as competent as the Contractor's Field Engineer, we changed the format of the Job Performance Aid, and changed it and changed it. Dr. John F. Foley, Jr. of the Air Force Human Resources Laboratory, Brooks AFB, Texas, gives a recent and comprehensive picture of how Job Performance Aids have changed in his report entitled <u>Executive Summary Concerning the Impact of Advanced Maintenance Data and Task Oriented Training Technologies on Maintenance, Personnel, and Training Systems</u>[1]. Of course, neither Dr. Foley, nor Dr. King in his article entitled <u>New Concepts in Maintenance Training</u>[2] has been able to cover the complete spectrum of the types of publications devoted to Job Performance Aids. What Dr. King does do, however, is to point out the distinction between publications serving as "book" knowledge and other forms of Job Training Aids which give "head" knowledge. Until very recently (circa 1974), the military and industry consumed much of its resources in "improving" Maintenance Job Performance Aids in the form of paper or plastic materials. In a few instances display boards were constructed which, figuratively, lit-up and depicted a block diagram of how an equipment functioned. Electrical switches were placed in convenient places to deenergize certain portions of the block diagram, and we then had a crude hardware maintenance Job Performance Aid.

Before we go too far, let's examine some of the attributes of a good Job Performance Aid and try to analyze the best way to accomplish such a maintenance or maintenance training aid for the Military Technician today.

[1]Report Number VASHRL-TR-24 by Dr. Foley, March, 1978.

[2]Aviation - Engineering and Maintenance, Nov/Dec 1978.

1) The Aid should cover an almost exhaustive amount of troubleshooting information, especially causes and effects which may not be apparent on a daily basis.

2) The Aid should be capable of helping to solve multiple malfunctions which exist separately or simultaneously.

3) The Aid should be rapid and allow easy access to malfunctions. It must also allow diagnostic troubleshooting to begin with ANY known sensory event not occurring properly.

4) The Aid should be capable of having its information revised or updated quickly and inexpensively without restriction as to whom is accomplishing the revision(s).

5) The Aid should help motivate the technician. That is, he must achieve success in accomplishing his maintenance or learning task.

6) The same Aid should be capable of being utilized with numerous equipments or models of equipments.

7) The Aid should also be an asset in helping to disclose weaknesses of Reliability or Maintainability in equipment design.

8) The Aid should be capable of being utilized in actual maintenance situations as well as "on the job" training situations. There should not be the need for complete duplication of maintenance material to achieve training material.

9) The Aid should have some method of being validated and verified prior to delivery to the customer. By this, we mean that the actual procedural information must be proven, not only the result of some test (i.e., is the sequence correct?).

10) The Aid should facilitate understandable communication from the operator, to unit maintenance, to shop or intermediate maintenance, and to depot or factory maintenance.

11) The Aid should be capable of backing-up BIT at any level of maintenance.

12) The Aid should be useable by experienced maintenance personnel and those who have not previously maintained a particular system. An important aspect would be to provide for those who have just matriculated from a basic course in electronics, mechanics, optics, or hydraulics.

13) The Aid should be capable of assisting Contractors and Customers to determine what should be a spare /repair part and what quantities are required for different scenarios or missions as well as Life Cycles.

14) The Aid should be one-man portable and easily stored. It should not require expensive and unusual storage facilities.

15) The Aid should be capable of producing a hard copy of the actual maintenance action performed by the technicians. This copy could then be used by supervisors to validate work accomplishment and to give further assistance to technicians.

16) Preparation of the Aid should allow the least possible human error.

Most naturally we have all answered these questions with either a retort of "this is impossible" or "I am doing this today". If your answer is "this is impossible", you must do some soul searching as well as - getting out into the world. If you have answered "I am doing this today", then for everyone's sake share what you have with the rest of the same community. What or who is your SOURCE? How can we implement it? What can we do to help?

The real message to this paper is to share what I and those dedicated people in our Company have been doing to provide a Job

Performance Aid which has most of the qualities just enumerated. Our SOURCE has not been one Military Specification but the combined intents of several, with a dash of Common Sense. We could not use the "paper" Job Performance Aid method because it would have become too bulky for any given system "larger than a breadbox". It needed today's "State of the Art" in electronics, and it needed definition and simplification of a concept I began over twenty years ago. The LOGMOD Methodology and Diagnostic Test Set are the result. Using the simple Logic Model Algorithm (probably known as a Maintenance Dependency Chart to most people) we recorded schematic information on a magnetic disc. With the aid of a processor, memory and readout device we have proven that most of the Aid Requirements could be met. The device is passive (not connected directly to an equipment being diagnosed) and can be hand transported by one individual with the same ease as carrying a 15" portable color T.V. set. Although we do not consider the present medium (LOGMOD Diagnostic Test Set) the ultimate in design for world-wide use, it is capable of providing most of the answers to our Job Performance Aid questions. Also, it is very difficult sometimes when showing or discussing the LOGMOD Job Performance Aid medium to really show the attributes of the entire "system". The system is not only the medium, but it is the use of a Logic Model Algorithm in schematic analysis, test messages, fault messages, and a "type of index". Presently, illustrations are still provided and keyed to paper or plastic reproductions. The Logic Model Algorithm plays the key role in affording a multi-useable Design, Reliability, Maintainability, Maintenance Analysis, Repair Parts Cost, Test Sequences Organizer, and Validator/Verifier. In the future, it will also add maintenance training to its repertoire. The Algorithm has been committed to a sizeable computer (apart from the LOGMOD Diagnostic Test Set) which has not changed in the last five years, yet has produced LOGMOD discs for mechanical, electro-mechanical, hydraulic, and purely electronic systems for the Army, Navy, and Air Force. In fact, each Service has procured at least one of the LOGMOD Diagnostic Test Sets. The U.S. Air Force, in an October 1978 report written by Major Billy F. Lacy and Captain John B. Berry[3], after three months of extensive testing using the LOGMOD concept and mechanism has concluded the following:

1) LOGMOD is a workable concept and could serve as an efficient and effective troubleshooting aid.

2) Subjects preferred LOGMOD over other troubleshooting aids (meaning T.O.s and FPJTAs) at the intermediate level of maintenance. Consequently there is a high probability of user acceptability if the LOGMOD concept is applied to other Air Force systems at this level of maintenance.

The Air Force report also states that the "LOGMOD potential has been validated". Mr. W. L. Andre of the U.S. Army Aviation Command's Research Technology Laboratory has made similar comments in the Army's public release to VERTIFLITE MAGAZINE (Sept/Oct 1978)[4] and the ARMY RESEARCH AND DEVELOPMENT MAGAZINE (Sept/Oct 1978)[5]. Mr. Andre has pointed out the uses of LOGMOD in design as well as in maintenance.

The question of whether the Government/Industry attacks at Job Performance Aids remaining in the paper form seems to have been answered. The mechanization of LOGMOD, claimed to have been highly improbable four years ago at the first of these Biennial Conferences conducted by the Naval Equipment Training Center, has now been accomplished. The conventional paper documentation, above which it replaces, equates to about one 5 1/2" (diameter) floppy disc to 500 pages of written material. There are no estimates of how much paper documentation the LOGMOD concept replaces when considering design influences, multiple malfunction strategies, and exhaustive malfunction diagnostics, because there exists no paper equivalent today. The stake has been cast and the fish dangling. Only those bold enough to take up the challenge will benefit from the nutrition and vitality that ensues from this new form of nonpaper, but simple, Job Performance Aid.

To those of you who take up the challenge, just a few words of advice overheard from several government personnel: make it so simple that children in grade school can use it; make it as light as a feather; give it the knowledge and memory of all equipment designers; and make it free of charge.

[3] LOGMOD DIAGNOSTICS Project Number 760701, Air Force Logistics Management Center, 15 October 1978.

[4] Vertiflite, LOGMOD-the Fault-Isolator, by William L. Andre, Sept/Oct 1978.

[5] Army Research and Development, Helicopter Fault Isolation Equipment Evaluated by Armed Services, by William L. Andre, Sept/Oct 1978.

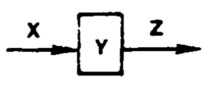
1.0 LOGMOD

The Logic Model Analysis Technique (LOGMOD) is a computerized maintenance and fault isolation concept that is considered proprietary to DETEX Systems, Inc., California.

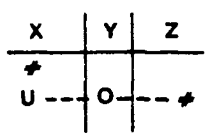
Basically, the technique involves the application of the LOGMOD computer program and the associated LOGMOD Diagnostic Strategy. The LOGMOD computer program, developed by DETEX Systems, Inc., accepts inputs in the form of dependency chains that show the interrelationships of each functional element (or group of components) of a design and generates a logic model for the design. The logic model is usually displayed as a chart with all the dependency chains organized in such a fashion that systematic fault isolation procedures can be observed through the application of the LOGMOD Diagnostic Strategy.

1.1 GRAPHIC DISPLAY OF BASIC LOGMOD CONCEPT

The basic form of a logic model is constructed by first listing all the functional elements (or groups of components) and their associated inputs and outputs. Next, procedural information is applied to establish the dependency of the output events on previous events and functional elements in the form of dependency chains. Events are things that are observable whether they can be seen, heard or measured using external test equipment. A dependency chain is graphically represented by a logic mechanism of three basic symbols: a pound sign (#), a character O and a character U. Below is an example of a simple logic model display constructed from the given functional block diagram.



Functional Block Diagram



Logic Model

The # sign denotes the event (or state). The character O denotes the functional element (or a group of components). The character U denotes the previous event which the event # is depending on. The example shows the dependency of the output event "Z" on the functional element "Y" in the presence of the input event "X". Using this scheme, dependency chains of complex electrical, mechanical or electronic systems can be constructed. Each dependency chain forms a horizontal line on the logic model display. Hence, the logic model is a symbolic representation of the functional operations of the system. For complex systems, the manual construction of logic model displays can be very tedious and time consuming. Through the use of the LOGMOD computer program, complex systems are modeled logically, very efficiently and easily displayed. In addition, changes can be made painlessly.

1.2 FUNCTIONAL LOGIC MODELS

The Functional Logic Model Display (as shown in Figure 1.1) shows each functional element and its interrelationships with other elements. In general, the relative position or order of the functional element (or part) in the columns from left to right is indicative of the degree of dependency of the functional part. The operational status associated with each functional element may be monitored at a pre-determined test point, and the measured result can be compared with the specification for that test point. The body of the logic model display portrays the dependency chain structure as the inputs are processed through the functional elements to produce the desired outputs. The complex relationships are clearly and precisely defined. In addition, logic models generated by the LOGMOD computer program are the ones with their dependency chains organized in a hierarchy of least dependent to most dependent. With this logical representation of a design, it is possible to structure a systematic approach to diagnostic testing and to the design for reliability and maintainability.

1.3 LOGMOD DIAGNOSTIC STRATEGY

The LOGMOD Diagnostic Strategy is a fault isolation methodology applicable to logic models developed through the use of LOGMOD computer program. The LOGMOD Diagnostic Strategy can be described as follows:

The logic model is entered at a BAD (out

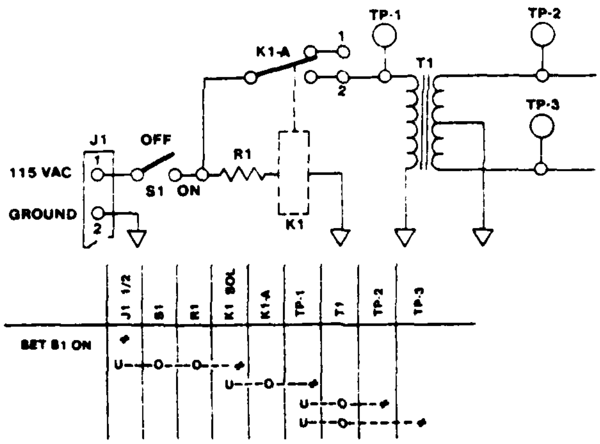


Figure 1.1 Functional Logic Model

of specification) terminal event either by observation of some indicator or through indication of a previous higher level test which narrowed the problem to this level. A terminal event is an event which no other event will depend on. The method of fault isolation used can be thought of as "the half-split method of good events". The first check is made at the related event nearest the input events (most upper left of the logic model display) in the dependency chain of the BAD terminal event. If this first test is GOOD (that is, within specification), then a second check is made at the half-way point between the GOOD event and the BAD terminal event. The half-way point is where the related events between the GOOD event and the BAD event are halved. If the second test is also GOOD, then the procedure mentioned above will be repeated. However, if the event test is BAD, that event's furthest left dependency (on the display) will be tested. Eventually, a line (that is, a dependency chain) is entered that has all of its input events test GOOD thereby, isolating the failure to the functional entity on that line.

2.0 LOGMOD PREPARATION

1) LOGMOD Algorithms already exist; therefore, no programming time is required to use them immediately.

2) LOGMOD Algorithms merely required knowledge inputs. These inputs must be made by either technical or managerial personnel with an understanding of some segment of a complete system.

3) Random inputs to the LOGMOD Algorithm will automatically be organized into one complete data base showing all interdependence of actions or components analyzed by all individuals.

4) LOGMOD inputs can be generated completely by company personnel. A relatively small capital expenditure for the use of the LOGMOD Algorithm would make the company self-sustaining.

5) Almost immediate productivity can be made of present company personnel (after a five-day training period by DETEX Systems, Inc.).

6) Its flexibility in use allows the analyst to provide a checkout sequence suitable to the equipment while never changing the exhaustiveness of testing.

3.0 LOGMOD APPLICATIONS

3.1 DESIGN

1) Disclosure of design information - This means the designer's notebook and thoughts that went into the design of a particular equipment are completely preserved from program to program and forever.

2) There is more use of equipment designer's time since he does not have to recall past designs to answer questions pertaining to that past design.

3) Equipment designers will always know the impact of their design on support activities before the hardware is committed to a final configuration.

4) It can be used to:

   a. Develop ATE.
   b. Work in conjunction with ATE.
   c. Provide a back-up for ATE when ATE is malfunctioning.
   d. Provide complete diagnostic capability when no ATE is available.

5) It can determine the following elements of support in its initial software stages:

   a. Test point placement for maintainability.
   b. Objective diagnostic times for each replaceable item - impacting decisions to make certain items more reliable and others not as reliable. The latter remark applies to mechanical parts working together where one failing requires a complete set to be replaced.
   c. Sequence of checking - All diagnostic strategies developed automatically by LOGMOD.
   d. Addition of item failure rates provides calculations of Mean-Time-to-Repair.
   e. Validates/verifies diagnostic strategies before equipment is fielded.
   f. Resource analysis tradeoffs - design expenditure versus support expenditure for any given life period.

6) Allows determination of correct and optimal Built-In Tests (BIT) for Aircraft, Marine, and Land Operational Systems.

7) Common Data Base for design and support decisions.

3.2 MAINTENANCE

1) Lesser skilled maintenance personnel perform fault isolations with the proficiency of higher skilled maintenance personnel.

2) Reduced maintenance time by using optimized search on an organized data base.

3) Does not require the maintenance technician to know design or operational features to perform maintenance.

4) Fault isolation is exhaustive, that is, faults can be isolated to any level desired.

5) Provides diagnostics equally as well for mechanical, hydraulic, electro-mechanical, electronic, optic, or any combination of the above.

6) Works equally as well with digital and analog electronics.

7) It reduces technical information analomies among Management, Design, and Support Functions.

8) No computer programming knowledge required by user.

9) Packaging concepts of LOGMOD devices run from large consoles to small pocketsized hand sets.

10) It can be used in spacecraft to enable astronauts to make "on the spot" diagnoses of malfunctions in the event they lose voice transmission or reception.

11) Maintenance technicians can isolate malfunctions in any equipment providing they know how to use general purpose test equipment.

12) Test equipment cribs could calibrate and maintain all types of equipment on or off-site in shorter time, because they do not have to refamiliarize themselves with an equipment they may see very rarely.

13) Virtually eliminates the need for the most important parts of a maintenance manual, i.e., troubleshooting, schematics, wiring or plumbing diagrams, and theory of operation.

3.3 TRAINING

1) It can be used as a training device with pictoral and/or sound information available which would be automatically cued by LOGMOD.

BIOGRAPHICAL SKETCH

Dr. DePaul is President and Chairman of the Board to DETEX Systems, Inc.; the creator of the Logic Model Algorithm and LOGMOD Technology; the original developer of MIL-M-24100 (now termed FOMM); and author of numerous papers on Integrated Logistics. His 24 years of experience include actual hardware design and support, Logistics Manager, and Director of a Systems Analysis Laboratory. His education includes: M.S. in Physics from Loyola University, Chicago, and Ph.D in Mathematics from the University of California, Irvine.

AIDING AND TRAINING: A PRACTITIONER'S PERSPECTIVE

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ABSTRACT

This paper presents a practitioner's view of aiding and training in maintenance. The paper traces the development history of aiding, in order to help focus attention on problems of application. General application problems are discussed, followed by suggestions for resolving the problems. The paper contends that aiding and training in maintenance represents an opportunity for the human factors community to make a vast contribution. However, the challenge requires resolution of application problems by the community.

As the title indicates, this presentation is from a practitioner's point of view. I was a member of what might be termed the "human factors research community" for a number of years and enjoyed it. However, for the past ten years or so I have been specializing as a practitioner (systems and human factors) and am also enjoying it.

Being a practitioner, I have taken certain liberties in this presentation that may not be permissible in a document by a researcher. For example, I fail to cite references when discussing work done by others. Therefore, you will have to take my word for the works. Also, much of my evidence is the product of repeated experiences rather than research data.

Despite the lack of research orientation, I hope the message has some meaning to the audience. I sincerely believe that the human factors community needs more practitioners who understand and appreciate the importance of research as well as apply the results of research.

I believe that both the human factors researcher and practitioner have much to contribute. Unfortunately, the failure to distinguish between the two has often led to counterproductive activities, which in turn has caused lost opportunities.

By properly integrating aiding and training, the human factors community can have a significant impact on improving the productivity of technicians. This potential is especially large in the field of maintenance. Thus most of my comments in this presentation are oriented towards maintenance.

At first I will try to provide a historical perspective of aiding. Then, I will discuss some of the more general problems usually encountered when applying the aiding concept.

Finally, I will make some suggestions which I believe would be helpful in realizing the full potential of integrating, aiding, and training in maintenance.

HISTORICAL PROSPECTIVE OF AIDING AND TRAINING IN MAINTENANCE

The Nineteen Forties (1940's)

Research in aiding appears to have started in the 1940's with some scattered research on job guides. Although the research efforts were not very extensive, they were quite productive. In fact, the presentation principles which we used to develop the current format were based on research data from the 1940's. More of such research is needed to properly advance the state-of-the-art in aiding and training.

The Nineteen Fifties (1950's)

Considerably more human factors attention was given to the aiding concept in the 1950's. Two major contributing groups were AFPTRC (Air Force Personnel and Training Research Center) and HUMMRO.

The most notable work by AFPTRC was its conceptual treatment of aiding. Aiding was defined as one of the three means of obtaining the necessary personnel performance capabilities, i.e., selection, training and on-the-job aiding. Although various researchers contributed to the

concept, the most prominent advocate of aiding (or then known as job guides) was probably Dr. J. Jepson Wulff. He was instrumental in showing that proper aiding was as important as proper selection and training of personnel. Fortunately, I was one of those so convinced.

One of the earliest attempts to apply the aiding concept in a weapons system was made by HUMMRO. Their MAINTRAIN consisted of a total set of job guides for supporting maintenance on a major weapons system. Dr Ed Shriver was the guiding force behind MAINTRAIN.

The Nineteen Sixties (1960's)

Today's version of aiding in maintenance really started to take shape in the 1960's. Three sets of events in the 60's were major contributors to today's aiding concept.

Troubleshooting procedures: Considerable research in proceduralized troubleshooting was conducted in the 1960's. Although numerous human factors researchers were involved, the most prominent were probably Dr. John Foley (then at Wright Patterson Air Force Base) and Dr. Jack Folley, the founder of Applied Science Associates. As is the case with Ed Shriver, both are still active in the aiding field.

Much of the human factors community's conviction of the power of troubleshooting procedures stems from the research in the 1960's. These studies gave quantitative evidence that there are more effective alternatives to restricting troubleshooting to highly experienced technicians supported by extensive and expensive training.

BAMAGAT aka SIMM aka FOMM: The BAMAGAT concept was introduced by personnel then at Hughes Aircraft Company. This was a new approach to aiding troubleshooting. Although there are various aspects to the concept, I believe that the most important was its chart form of presenting component dependencies. This technique is called the Maintenance Dependency Chart (MDC). Although BAMAGAT was changed to SIMM (Symbolic Integrated Maintenance Manual), and then to FOMM (Functionally Oriented Maintenance Manual), it retained the MDC as an intregal part of the concept.

There are other aspects of the SIMM/FOMM package, such as schematics with functional boundaries, etc. However, these techniques were not necessarily unique to BAMAGAT. The MDC is unique to SIMM/FOMM and I believe the major contributor to the effectiveness demonstrated in various tests. Unlike other aids, the SIMM/FOMM package is useful primarily to the experienced and highly skilled technicians, and requires quite extensive training with the aids. However, SIMM/FOMM represents a significant simplification of information normally presented in schematics and other complex diagrams. In contrast, the SIMM/FOMM treatment of repair-type activities is fairly conventional.

PIMO (Presentation of Information for Maintenance and Operation): I have been applying the aiding concept since I first met Dr. Wulff in 1957. However, my first formal study of the concept did not occur until the mid-1960's with Project PIMO. The project was sponsored by the Ballistics Systems Division (now SAMSO) of AFSC. The project was the brain child of Mr. Charles Schaffer (then of BSD) and Dr. Ed Triner (then of AFSC headquarters).

We tried to take full advantage of the state-of-the-art of aiding at that time. Therefore, we tried to take full advantage of the work done by such contributors as Drs. Shriver, Foley, Folley, and the developer of BAMAGAT. In fact, we adopted the BAMAGAT approach to troubleshooting aids.

Project PIMO made two major contributions to the aiding concept as is known today. One is the presentation format. This format was based on presentation principles developed from synthesizing available research data in the behavioral sciences. As I mentioned before, most of the relevant research were conducted in the 1940's, or earlier. The basic PIMO format is currently being used in most Job Performance Aids.

The second major contribution of PIMO was relating the effect of aiding to system effectiveness. Since we used the systems approach, we expressed the improvements in technician performance (from aiding) in terms of their effect on such system parameters as improvement in operational readiness, reduction in spares consumption, reduction in maintenance manhours, etc. Such expressions helped to make the DOD decision makers aware of the potential for aiding.

The Nineteen Seventies (1970's)

The activities in aiding picked up considerably in the 1970's, primarily in support of maintenance. Only a smattering of research was conducted during the 1970's. Most of the activities were in demonstrating the concept. Such demonstrations helped convince many that aiding must be applied. However, the lack of significant advancements in R & D indicates an oversight which should be resolved if we expect to make aiding and training an effective tool in maintenance.

Vietnamization: The first major application of the aiding concept was in support of the Vietnamization program. At that time, the term Job Performance Aid (JPA) was officially adopted by the Air Force.

The basic objective for applying the JPAs was to convert from (1) training in English in the United States to (2) training in Vietnamese in Vietnam. This objective was met with the help of aids. However, JPA usage in the field was less than desired.

Some squadrons used the aids quite extensively. Other squadrons did not use them at all. This lack of usage was the first concrete evidence of the importance of applying the systems approach when installing the aiding concept. This approach must include not only integration of aiding with training, but also proper preparation of

management, of the technicians, and other interfacing activities.

At the time of the program, the program monitors though such preparatory efforts were fringe benefits. They did not realize that the proper aids were "necessary but not sufficient." That is, proper maintenance cannot be achieved without effective aids. However, the aids per se will not improve performance. The other parts of the system (most notably training) must be adjusted to realize the benefit of the aids.

Air Force Applications: The Air Force far out distances the other services in its application of the aiding concept. At last report, about half a dozen systems are being supported by aids of one sort or another.

Unofficial reports indicate that considerable adaptations have been made by project personnel, some of which have been counterproductive. However, the most serious shortcoming is the fact that such aids apparently have not been integrated with training. Thus, the aids serve as more usable manuals, but have not provided the types of benefit possible when integrated with training and applied in a very stringent manner.

Navy aiding program: The Navy started studying the concept of aiding in maintenance in the early 1970's. Unfortunately, the Navy is still studying the concept.

As with the Air Force, the Navy has made very little change in its approach to maintenance training, with one major exception. This exception is that the Navy currently emphasizes the use of maintenance manuals in its training program.

In the past, training developed its own maintenance procedures and tended to ignore the maintenance manuals. Today, the students are "driven" to the manuals. The course essentially leads the students through the manuals. Generally, we would agree with this approach. However, the problem illustrates the weakness of not integrating aiding with training from either direction. The emphasis on using manuals in training has not really helped much because the manuals are not usable. Once the student leaves the training environment, the manuals are put back on the shelf again.

Such emphasis in training is crucial when usable aids are provided. However, when the only manuals available are conventional manuals with severe usability problems such emphasis merely tends to reduce the credibility of training.

Applications in the Army: The Army started attending to the problem again after the Vietnamization program. The Army is the only service formally integrating aiding and training documentation with the Integrated Technical Documentation and Training (ITDT) program (described in another paper).

The Army's effort is definitely a step in the right direction. However, integration has to go far beyond just the documentation. The manner in which the technicians are trained, the work allocation, etc. must all be integrated.

Industrial and other non-DOD applications: In the past four or five years, Xyzyx has been focusing its attention on industrial and non-DOD clients. We have been applying the concept of integrating aiding and training for both operations and maintenance. We are usually called in to help fight "fires", but we also have had opportunities to install such systems in a less stressful situation.

Usually, we have had the advantage of being invited by the client. Such invitations usually result from a manager recognizing that a given personnel performance problem is related to some documentation and/or training problems. This does not mean that all the relevant parties greet us with open arms. However, by starting from the performance problems of personnel, all parties are forced to look at the contribution of documentation and training (ours or conventional) to people performance. In such cases, aiding and training are usually perceived in a highly positive manner.

We have had gratifying successes when we are allowed to integrate with not only training but other interfacing areas such as performance standards, certification, advancements, etc. Our most successful application was obtained for a new plant built in Ireland to assemble pacemakers.

The standards for performance were based on the performance achievable when supported by aids. Training was then designed to prepare the technicians to the required standard, which required proper introduction to and maintenance of performance with aids.

Since the approach was introduced as an integral part of plant start-up, no acceptance problem occurred. We realize that such a complete approach is not always possible in the military services. However, the experience, as well as other related experiences in industrial settings, indicate the feasibility of integrating aiding, training, the setting of performance standards, etc.

APPLICATION PROBLEMS

The experience gained in applying the aiding and training concepts to maintenance is quite useful in plotting future applications. Probably the most important part of the experience is the identification of pit-falls which we should try to avoid in the future. Five of the main problems in applying aiding and training in maintenance are discussed below.

The Camouflage of "Conventionals"

Despite the recent emphasis on maintenance, inadequacies in maintenance have generally been ignored. Man-

[illegible] accept poor maintenance as the standard. For example, the performance of the experienced technician is used as a standard in new systems or in establishing expectations for new technicians. People tend to forget that the measured error rate and high life cycle cost stems from the performance of the experienced technician.

I do not mean to deprecate the maintenance community. Most maintenance technicians with whom I am acquainted have a tremendous amount of capabilities. However, they have essentially an impossible task to perform. For one, they are saddled with maintenance manuals which can't be used except with extraordinary efforts. The training they receive is often irrelevant and frequently ineffectual. Yet, they are expected to keep multi-million dollar systems in operation. The inadequacies of support, as to be expected, results in degradation of performance. For example, measurement of error rate indicates that the productivity of maintenance technicians is about one half of what it can and should be.

Despite evidence of inadequacies in performance, most managers pay little attention to the problem. To them, the very fact that manuals are being produced and students are being processed are evidence that sufficient attention is being given to documentation and training. Often, the attitude seems to be that with all that effort and dollars being expended, training and documentation can't be "all that bad." They fail to ask what is the "return on investment."

In other words, the vast amount of work associated with conventional manuals and training has camouflaged the seriousness of the problem. And the camouflage has been effective. Since the system managers have paid little attention, the researchers have not been pressed to attend to the problems either. The result has been that maintenance and its associated problems of documentation and training have been the "forgotten stepchildren" of systems design.

Resistance of Publications and Training Management

Unfortunately, no effective performance criteria have been established for publications and training. As indicated above, training tends to be judged on the basis of the number of students processed through the classroom. Manuals tend to be judged on the basis of the number of pages produced. Little attention is given to the usability of the manuals or the performance capabilities of the students.

The lack of relevant criterion has created a situation wherein there is no effective motivation to change. Managers of publications and training efforts are usually judged primarily in terms of whether they remain within budget. Little or no attention is given to whether their efforts contribute to operational readiness or other system criteria. Thus, it is to the manager's advantage to maintain the status quo.

Any deviation from the status quo increases the risk of exceeding budget. If a change is made and the technicians become more productive, the publications and/or training manager does not share in the benefits - except possibly for a compliment. However, if the budget is exceeded in the process of trying to improve the situation, the managers are chastised accordingly.

The above may be an overly harsh assessment of the situation, but one that we find again and again in both governmental agencies and industrial firms. Some changes are in evidence, but such changes have been relatively pain staking and slow.

The recent emphasis on life cycle cost, productivity, and (in the DOD) improving operational readiness have helped to shake some people out of their lethargy. Consequently, there seems to be a new awareness of maintenance associated problems. As discussed below, the human factors community can be a significant contributor to solving the maintenance problem.

Scarcity of Usable Data

A major problem for the practitioner is the scarcity of relevant research data. We agree that there should no longer be a need to conduct trade-offs between aiding and training. Both are needed and should be integrated. However, there are various allocation decisions which must be made by practitioners on a system-by-system basis. For example, how much hands-on practice should be scheduled in training if the technician is to perform with aids in the field.

The question of "how much" hands-on training is an especially important question in maintenance. The greatest percentage of jobs assigned to a maintenance technician tends to be jobs occurring at very low frequency, i.e., once or twice per year or lesser frequency. In such cases, will any hands-on practice during training be of any value? There is some reason to believe that the most beneficial effect of practice in those situations is the confidence gained (of the aids) by the student.

Another allocation decision is whether to provide a generic procedure for multiple items supplemented by training, or a specific procedure for each item. There is some indication that such mechanically-oriented maintenance activities as "remove and install" and "assemble and disassemble" can be effectively supported with generic procedures supplemented by training. The technicians will still need aiding support but the characteristics of such aid will be considerably different from the procedural JPAs so common in the demonstration studies.

Another area requiring study is the rate of forgetting associated with different amounts of practice of maintenance procedures. Such research is needed to establish priorities for assigning practice sessions.

It is impossible to provide practice sessions for all activities. Certain activities should require no training due to the infrequency of occurrence in the field. Other activities occur so frequently that most of the necessary replications for learning can occur on the job. However, the

practitioner needs to have some idea of the maximum interval between sessions which will inhibit forgetting of key parts of procedures.

The above are only <u>some</u> of the data voids. We believe that the entire approach to hands-on training and systems training need to be supported by research data.

As practitioners, we must provide answers to our clients. Without the data, we are forced to select an approach on the basis of judgement only - or fail to change from a conventional approach. For example, many programmers applying the aiding concept still provide more classroom training than is needed (we think) since we do not have data to support our judgement. This overtraining time would be more effectively applied to more relevant systems and/or hands-on training.

The Professional Researcher

Being a young discipline, the human factors community hasn't learned to differentiate between research and applications. We have found that it takes entirely different skills to be a successful researcher as compared to being a successful practitioner. In many cases, characteristics contributing to successful research are counterproductive in an applied setting.

Part of the reason why many promising human factors areas have not borne as much fruit as it could is the running conflict between the researcher and the practitioner. There are many researchers who "dabble" in applications. Such researchers tend to apply research criteria for applied problems. This often results in recommendations to study the problem some more, and never quite helping organizations solve their problems.

Lack of Integration of Aiding and Training

This conference should be very helpful in "spreading the word" for integrating aiding and training. Currently integration of documentation and training is more rhetoric than action. I believe the lack of integration applies to both the research community as well as the practitioners.

The general conflict between publications and training groups is fairly well publicized. Unfortunately, such a conflict also exists between aiding researchers and training researchers - despite protest to the contrary by the researchers.

Training researchers tend to distrust the aiding researchers because the latter seem to want to eliminate training. In turn, the aiding researcher tends to aggravate this distrust by overzealous selling of the aiding concept.

Aiding and training in maintenance represents an opportunity for the human factors community to make a significant contribution. To do so, the types of pitfalls mentioned above should be avoided. Some suggestions to help do so are discussed below.

SUGGESTIONS FOR APPLYING AIDING AND TRAINING IN MAINTENANCE

Being a practitioner, my suggestions for applying aiding and training in maintenance tend to be heavily biased in favor of applications. I believe <u>application</u> is one of the primary needs of the human factors community at this time, although more research is also sorely needed. Unfortunately, justification for such research tends to be weak without a competent applications program.

Develop a Group Specializing in Application Within Each Service

Currently, there appears to be no one in charge of or apparently interested in an <u>integrated</u> application of aiding and training. In fact, integrated application of human factors variables tends to be inhibited by the specialization of research centers, e.g., centers for training, hum engineering/design, personnel, etc.

Part of the problem results from confusing application with research. That is, research is understandably organized around such functional areas as training, human engineering/design, personnel, etc. Application requires the consideration of data from <u>all of these areas.</u> This integrated application is especially needed in maintenance. Yet, research centers hesitate to go beyond the functional boundaries of the center. Consequently, solutions to problems tend to be highly biased in favor of the center's specialty.

In addition, there needs to be a more effective bridge between the research community and the systems development community. That is, someone has to bridge the current gap between (1) the researchers in training, aiding, personnel and human engineering, and (2) the various groups involved in developing systems such as design engineering, publications, training centers, etc.

Evidence to date indicate that research centers are not properly organized to respond to <u>system needs.</u> In addition, researchers are generally not inclined to attend to application-type problems, neither individually nor as a group. I believe significant advancements in <u>applying</u> human factors variables can be made by a group specializing in applications.

This group would develop specifications and guidelines to be used in system development/refinement programs. Also, the group would communicate voids and research needs to the research community.

Some centers have tried to establish such a group. However, success has been quite limited because the group is treated more as a necessary evil. The group is seldom given any stature, get limited support from the researchers, and usually operate with a very limited budget.

Select, Develop and Encourage Practitioners

The types of professionals required to properly implement the systems application group are practitioners, not researchers. Currently, applied-oriented researchers tend to be at a disadvantage in a research community. They tend to be looked upon as less of a professional than a researcher. Usually, such an applied - oriented researcher tends to get less support and encouragement at a research center. Given such an environment, it is not surprising to find that the centers do not spawn very many practitioners. Yet, those who have successfully overcome such barriers tend to be very good practitioners.

I believe both application and research would be greatly aided by more trained practitioners. When housed in a systems application group, their effectiveness could be considerable - - both for the systems affected as well as the research community and such functional groups as technical publications, training centers, etc.

Involve Practitioners in Planning Applied Research Programs

Most applied research programs tend to depend primarily upon the researcher's perception of the needs. The researcher's view of the world tends to be considerably different from the practitioner's view. Thus, such applied research programs often "miss the target," i.e., fail to provide data which are useful to practitioners. The research programs in aiding and training in maintenance is no exception.

The practitioner's needs should be considered in developing applied research programs. This can be accomplished by such accepted mechanisms as workshops, surveys, or an Ad Hoc committee.

Apply the Systems Approach in Planning an Application Program for Aiding and Training in Maintenance

In order to realize the full potential of aiding and training in maintenance, the concept needs to be applied widely, as well as effectively. Often, such wide applications (especially in a limited time period) result in mass confusion which in turn severely dilutes the effect.

The systems approach should be very useful in developing an objective and properly integrated effort. This approach would include proper definition of the objectives for the program, derivation of requirements for sub-programs, design of sub-programs to meet the requirements, and standards for measurement.

BIOGRAPHICAL SKETCH

Dr. Kay Inaba
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Dr. Inaba is the founder of Xyzyx and was a co-founder of Serendipity, Inc. He has been applying the aiding and training concept for over 20 years. He headed the team which developed the PIMO Job Performance Aid concept. He also developed the concept of functional simulation of maintenance systems.

THE NEED FOR A PERSONNEL SYSTEMS VIEWPOINT IN THE DESIGN OF IMPROVED MAINTENANCE TRAINING

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ABSTRACT

Successful development of a maintenance training improvement program requires the inclination and capacity to perceive the problem from a personnel systems viewpoint. If anticipated payoffs are to be realized, interfaces among the various system elements must be appraised jointly from a cost tradeoff standpoint. This premise is particularly true for maintenance training which is one of the more expensive and risk-inherent investments in present day personnel systems. In response to the need for a personnel systems design framework, the Integrated Personnel Systems Approach (IPSA) was devised which includes a tradeoff analysis model. IPSA was then used to evolve a personnel system concept called EPICS for Enlisted Personnel Individualized Career System. EPICS includes such features as enriched and hybrid job performance aids, deferred pre-assignment training, individualized career advancement, integrated shorebased and shipboard training, alternative skill acceleration and job enlargement training paths, and transition adaptation training. It is recommended that an approach like IPSA be employed along with increased sensitivity to the personnel system viewpoint within professional and organizational communities in order that our steadily decreasing personnel resources may be employed more effectively.

INTRODUCTION

The Problem

Currently, the Navy and other services are faced with increasing maintenance training costs, shrinking budgets and declining entry level skills along with unfavorable attrition and personnel dissatisfaction. With steadily increasing hardware complexity, existing personnel systems are constantly challenged to provide resources that can fulfill operational and maintenance requirements at an affordable cost. At present, nearly 60 percent of total life cycle costs are attributable to personnel (U. S. Commission on Defense Manpower, 1976). The relative costs of training are sufficiently high to attract the attention of the OMB and the GAO.

Clearly, traditional approaches to personnel development must be scrutinized closely, and other approaches and concepts for utilizing our personnel resources identified and appraised. The scope and urgency of the problem demands new initiatives and, particularly, innovative thinking with respect to utilizing availabe technology that might be brought to bear on the problem.

Traditional Approach

In the past, selection, assignment, and training have been the preferred approaches for producing the people resources required. Training typically is given major emphasis, to the extent that, today, relatively huge training investments are made in personnel before they have an opportunity to demonstrate their adaptability to shipboard life or their on-the-job proficiency. Loss rate prior to EAOS for these first-term enlisted personnel is about 42% with an 85% turnover at the end of their first enlistment (CNET Report to CNO, 1978). The cost of providing maintenance training for those personnel approaches \$30,000 per individual (CNET Letter, 1978)

Such an approach is clearly not cost-effective. Training is an important and vital means for developing the level of skills and knowledge needed for the more advanced technical jobs, particularly for the career force. However there is substantial evidence that heavy "front end loaded" training is not the most cost-effective route to follow in preparing recruits for their first technical job in the fleet

[illegible] individual's adaptability [illegible] member before such large investments are made. Stated another way, we need to defer [illegible] dollar investments in training until such time as the [illegible], concerning expected payoffs can be substantially reduced.

Maximum investments in formal training is not the only instance of a sub optimum approach to problem solution. Historically, the approaches generated to relieve the problems noted above have addressed only specific aspects of the total personnel system. That is, we tend to see the problem as a "selection problem" or a "training problem" or "retention problem." We seldom have the inclination or insight to perceive such problems as a set of interrelated symptoms of a personnel system problem.

A significant example of what can result from the lack of a system's viewpoint was reported in a study by Hansen (1977). Job aids were introduced into an existing system without due regard for interaction with job design, career advancement, training, or organizational structure. The subjects soon became anomalies since they were considered unacceptable for assignment to many job tasks for which JPAs were available, rejected by supervisors and non-JPA oriented peers, and were unable to pass knowledge-based tests for advancement in rank even though they were satisfactorily performing the jobs under study. As one might expect, severe personnel turbulence resulted and potential benefits from the use of job aids were lost.

Although the concept of system has been with us for over 25 years, there still exists certain factors which tend to preclude or at least diminish its full consideration. That a certain amount of tunnel vision exists perhaps should not be surprising. Our professional and organizational structures tend to direct our viewpoints in a parochial manner. Melton (1962) noted that the psychotechnologies associated with personnel selection, training, and human engineering were developed more or less in isolation from one another. Different specialists tended to promote their specialty more than the integration of specialities. Hence, those in the training establishment tend to see most personnel problems with solutions through new instructional technology innovations, while our colleagues from the selection and placement realm would like to answer the problem with a new selection test.

The most significant inhibitor to the systems approach has been the management organization employed by the military and industry for the development and use of hardware systems. This is particularly acute in the Navy where the various elements of the personnel system are compartmented in as many bureaus and offices. No force has been available to date to achieve an effective integration of those elements. In the research and development community, our efforts are largely directed by the label attached to our organizational unit, or by the particular title (and funding source) associated with the program element which constitutes our job. Hence, we tend to be predisposed toward applying the associated technology.

In itself, a singular approach toward the solution of *a personnel problem is not necessarily inappropriate* as long as the interaction of that particular element with other system elements is considered and evaluated. Most often though, we proceed with a singular solution oblivious to significant negative impacts with other system elements or of opportunities to greatly enhance the payoff of our particular approach by optimizing its relation with other system elements. An additional failing of the singular approach is that the nature of the real problem is seldom thoroughly understood without the broader viewpoint of the systems approach.

Background and Intent

We have a program at NPRDC which began with the objective of evaluating the cost effectiveness of various mixes of job performance aids in the fleet. Our first step in the program was to convene an invitational conference to discuss the state-of-the-art in JPA technology and to become aware of any implementation problems (see Booher, 1977, for the proceedings).

As a result of that conference, it became obvious that our orientation had to be broader than just job aids and training. The need for a total systems approach was vividly clear. As a result, we subsequently assembled a technique we call the Integrated Personnel Systems Approach (IPSA). Using IPSA, we evolved over time an experimental personnel system called the *Enlisted Personnel Individualized Career System*, or EPICS.

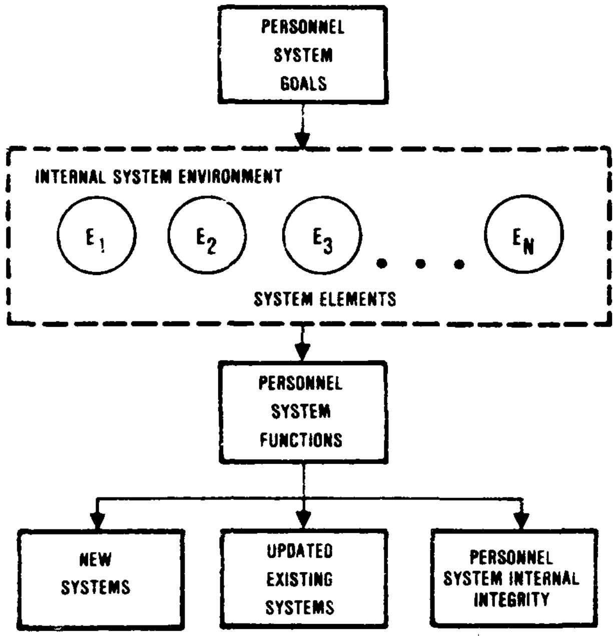
The intent of this paper is to discuss the basis for IPSA model development and use and to report on the characteristics of EPICS. It is believed that IPSA applications within the realm of improved maintenance training initiatives are indeed extensive.

INTEGRATED PERSONNEL SYSTEM APPROACH

It is not the intent here to belabor the reader with yet another philosophical exploration of the term "system." *The intent is to outline a brief and hopefully useful framework* for relating the Integrated Personnel System Approach (IPSA) to the conception, design and development of personnel systems. Figure 1 is a graphic depiction of the system's concept.

Definition of System

First, the definition of a system is to a large extent arbitrary and it can usually be said that what is one person's system is another person's subsystem; that is, there is a hierarchical relation between system levels interrelated by underlying primary goals. For example, a Navy personnel system might be considered to be embedded in a large, supra system called the Navy warfare system. Most of us are familiar with the concept of a "man-machine" system, promoted by the human factors community. Hardware is important to the personnel system concept; however, the *orientation is to consider simultaneously the requirements* of all hardware systems on an on-going basis and not just a single man-machine system design event.



SYSTEM MISSIONS - SUBGOALS

FIGURE 1. Taxonomy of a Personnel System

Taking the lead from Fitts (1959), the following definition of "system" is offered: "An assemblage of elements engaged in a mutual striving for a common goal(s) tied together by an interactive flow network where the output of the system is a function of the characteristics of the elements and of their interrelations."

According to Meister and Rabideau (1965), a system can be characterized by the following taxonomic terms.

System Goals

- Primary
- Secondary

Environment

- External
- Internal

Elements

Missions

Functions

Each of these terms is explored briefly below.

System Goals. A primary discriminating feature of a given system is its goal or purpose. Goals may be either primary or secondary. Primary goals relate directly to accomplishing the system's basic missions. Secondary goals are tied to supporting elements and are directed to insuring that the integrity of the system can be maintained so as to fulfill the primary goals. It should be noted that inadequate approaches to fulfilling secondary personnel system goals (motivation, morale, job satisfaction, retention) and thereby failing to maintain system integrity can result in system operational degradation and ultimately to system failure.

The primary goal of a personnel system is to acquire, develop, support and sustain the necessary human resources to meet the required qualitative and quantitative personnel and performance requirements imposed by the Navy's warfare and support systems. Subgoals relate to (a) meeting the requirements of new hardware systems, (b) responding to modifications and updates of existing hardware systems, and (c) dealing with perturbations within the personnel system's internal environment.

Environment. A system has both an external and an internal environment. The external environment establishes boundaries around the system, and defines what constitutes the system by identifying those objects excluded from the system and those that are included in the system. For example, in the definition of a personnel system, the hardware systems with which the personnel system interacts is a part of the external environment. The internal environment consists of those elements which make up

the system such as personnel resources, training elements, career structure, control/management structure, and so forth (see below). The boundary between the system's external and internal environments can be quite loose. The importance of maintaining the internal environment is second only to the system's primary mission.

To manage itself properly, the system must be able to sense the effects of its actions on the external environment and to respond to those effects accordingly. This implies the existence of a well-developed and continuously operating feedback mechanism. As a part of the feedback provision, the system must be able to recognize when the integrity of its internal environment has been compromised and be able to restore itself.

System Elements. System elements compose the system and provide the means for its operation. For example, a nonexhaustive set of possible personnel system elements might include:

- Personnel Resources
- Occupational Structure (Job Design)
- Training & Education (shorebased, shipboard, etc.)
- Performance Aids
- Career/Advancement Structure
- Procedures/Rules
- Organizational Structure
- Technical Data
- Control/Management Structure
- Support Elements
- Technology Development

A critical point here is that to have a true system, the elements must be interactive. It may be that some elements are treated as dependent variables and others as independent variables and this may change depending upon the nature of the particular system goal addressed. But interaction is imperative. For example, the training element must not be treated independent from the personnel resource element, the job structure element, or the performance aiding element. A set of elements working independently without interaction and feedback loops does not constitute a system since there is no mutual striving toward a common goal.

Missions. Missions are subsets of system primary goals. Establishing mission objectives provides for defining a specific system goal and facilitates the more precise development of a system to meet those goals. Any personnel system would have the capacity to meet several types of missions. For example, relating missions to system goals noted above, one system mission might be to fulfill the personnel system needs of a new surface ship platform, or a new weapons system being installed on a current ship. Or, a mission could involve responding to a subgoal associated with the existing personnel system's internal environment to protect against loss of its integrity, such as an unacceptably high first-enlistment attrition rate. The mission the personnel system is to fulfill also establishes the standards for system performance; that is, the objectives to be met stem from the specific mission to be performed.

Functions. Personnel system functions describe the manner in which system missions and ultimately system goals will be achieved. The function is the "how" of system operation and it relates directly to a particular system element. For example, a set of functions which might be associated with a personnel system includes:

Search	Communication/Control
Acquisition	Training
Screening	Education
Assignment	Aiding (JPAs)
Advancement	Evaluation
Supervision	Distribution
Administration	Support
Compensation/Reward	

Personnel System Development

The prior discussion concerned the definition of a personnel system and its components. This section concerns the application of those constraints in the conception, design, development and evaluation of a personnel system concept. Figure 2 provides a graphic description of this process.

A primary input to the system development model is the requirements and objectives derived from system goals and associated with the mission of interest. In some instances the mission will be defined by several hopefully congruent objectives or subgoals, such as "provide the necessary levels of personnel capabilities without increasing manning levels or training costs." Or, the objectives might relate to internal environment problems, as noted earlier, and concern high turnover, skill degradation over time, or ambiguous advancement channels.

Equally important to the development is identification and analysis of the constraints, limitations, and assumptions within which the design must be conceived. These factors are not an actual part of the system but they nonetheless play an important role in its design and operation. Examples are (a) operating environment, (b) hardware system interface complexity, (c) available manpower and skill levels, (d) funding, (e) technological gaps or lag,

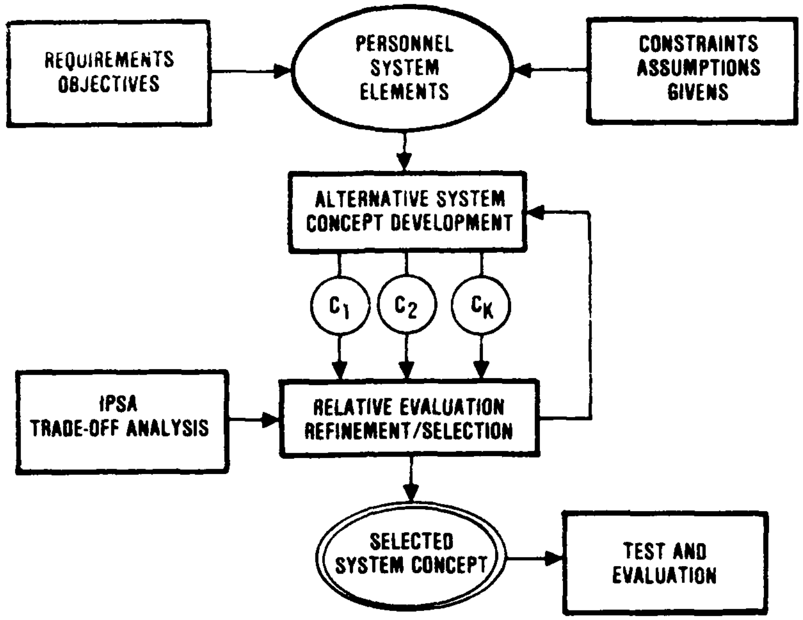


FIGURE 2. Application of Integrated Personnel System Approach

and (f) time schedule. There are, of course, numerous such variables which limit, moderate and constrain the various system design concepts which might be conceived.

An important aspect of the IPSA concerns the joint consideration of personnel system elements (at least those most relevant) within the pattern of constraints extant to achieve the stated system objectives. An important feature of this procedure is the capacity to conceptualize various approaches to the problem through alternative system concept developments. This provides the designer a powerful tool by which he can explore various ideas for utilizing system elements for a particular set of objectives and constraints. As illustrated in Figure 2, several alternative concepts or variations may be identified. The problem here is that all system concepts cannot be developed and implemented to test their relative ability to meet mission objectives. This must be done analytically, at least in most instances. IPSA includes the use of a tradeoff analysis model to explore and contrast the various system approaches. This model is currently under development at NPRDC with a preliminary edition due to be completed shortly.

As usual, the utility of the tradeoff model currently is limited to lack of objective data to explain quantitatively the interrelation among the numerous variables. However, even using simple algorithms (see Booher, 1978), one can predict the direction of influence (positive or negative) on the evaluation criteria selected for relative appraisal of system approaches. However, with the availability of necessary functional data and computer program, the power of the model as an integrated personnel system design tool will be greatly increased. An example of a current question we would like to explore using the model concerns the relative saving in training resources (particularly shipboard) through the use of enriched* job performance aids.

APPLICATION OF IPSA

The Integrated Personnel Systems Approach, outlined previously, was employed to develop an innovative nel system concept where joint consideration wa. primary system elements. A brief description of the approach taken and the result follows.

Goals and Objectives

The primary goal of the system development was to improve the material readiness of Navy electronics-based systems through enhanced effectiveness of the first enlistment manpower force at an affordable cost. Secondary goals or objectives included:

1) Identify, appraise, and implement any available personnel system technologies which would act to reduce current equipment maintenance costs and improve system availability.

2) Reduce the current investment in shorebased formal maintenance training provided prior to first duty assignment. Allow for redistribution of maintenance training resources.

* Refers to JPAs with instructional information integrated with the usual procedural data.

3) Provide for improved utilization of "lesser-aptitude" personnel (i.e., those who currently are considered "non-school eligible").

4) Identify and counter those characteristics of the current personnel system that contribute to demotivation, personnel turbulence, failed expectations and attrition.

5) Ensure that enlistees have the opportunity to obtain a credible amount of technical training that is transferable to civilian life during the first four-year enlistment.

The EPICS Concept

Considering the goals and objectives above and employing the IPSA, a personnel system concept was evolved called EPICS, "Enlisted Personnel Individualized Career System." A graphic depiction is provided in Figure 3. A brief description of its structure and provisions follows. For a more detailed discussion, review of two NPRDC documents is recommended (Blanchard and Laabs, 1978; Blanchard and Smillie, 1979).

The primary path of the model is depicted by the horizontal left-to-right flow. An acceleration path proceeds through skills preparation events to formalized skills training ashore. Remediation loops are provided at the various screen/assessment events to provide additional opportunities for reevaluation and entry into the main career path should individual assessment be negative. The job enlargement paths, which parallel the main career path give individuals expanded reponsibilities at specified skill levels with the continued opportunity for entry into the main career path when qualifications are met.

The model shown is directed primarily at four-year obligors with the provision for a two-year extension to qualify for system technical training ashore. It is anticipated that maximum effect of the EPICS model would be realized with mental group Category IIIA and IIIB individuals. Some payoff could be realized from Category II; however, competition for upper-level resources would probably cause a truncation around an AFQT score of 70.

Three primary skill levels are proposed for purposes of personnel organization and progression during the first

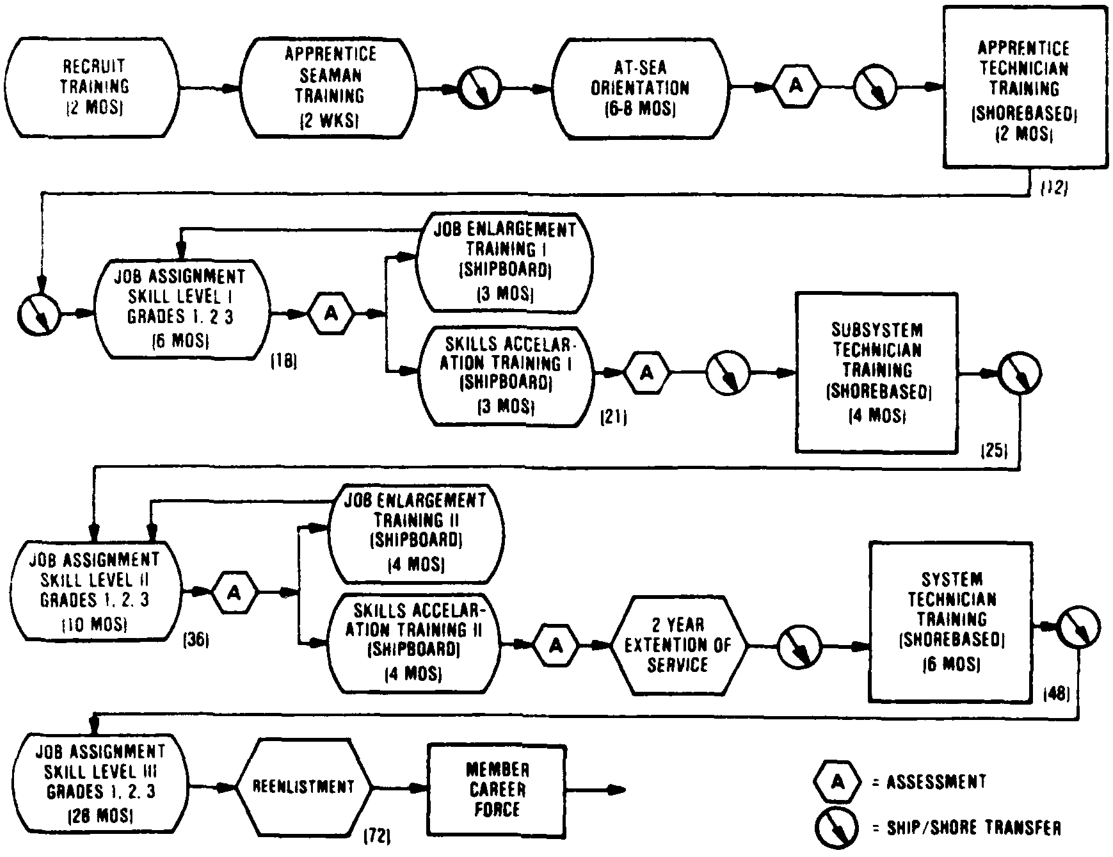


FIGURE 3. Enlisted Personnel Individualized Career System - EPICS

six years of service: (1) apprentice technician (novice), (2) subsystem technician (intermediate), and (3) system technician (advanced). A fourth skill level that might be used is "Master Technician." Within each skill level three grades are proposed to provide for rather immediate reward appropriate to increased responsibility and proficiency.

EPICS incorporates the "deferred training" concept in which the recruit is sent to sea after apprentice seaman training for a shipboard orientation period of from six to eight months, depending upon ship deployment schedules. The idea here is to get the individual on the job as quickly as possible and ensure that he is contributing effectively to ship's work with limited initial investment in formal training.

Deferred training is supported by job performance aids. Note that we are <u>deferring</u> training, not eliminating it. The same levels of technical training would be required, but delivery would be distributed across the individual's term of obligated service. At first, the investment is made in the "book", later, after the individual has demonstrated his adaptability, interest, and motivation, the investment shifts to the "head" via technical training.

JPA support is highest during At-Sea Orientation and Skill Level I work. Following Subsystem Technical Training, 25 to 30 months of service for an individual who has progressed through the skills acceleration path, emphasis on getting the job done with JPAs will have shifted significantly to emphasis on training to develop the individual as a potential career force member.

Other provisions, features and characteristics of the EPICS concept include:

1) Training, experience, and promotion paths are designed so that a path for advancement is always available to a motivated, deserving individual. This feature provides for acceleration through the system of those individuals considered career force candidates. Also, it ensures the <u>opportunity</u> for technical training <u>to all enlistees,</u> not just to those labeled "school eligible" as determined by written tests.

2) Transition adaptation training is included as a part of Apprentice Seaman Training and At-Sea Orientation to provide the recruit with the skills to help him cope with the transition to military life, and particularly to life aboard ship.

3) An EPICS Sailor's Handbook is envisioned which will detail the various career progression and training paths within the system along with qualification standards. Using this handbook, each sailor can plan his own individualized Navy career. If he is frustrated at some point, other avenues available to him are clearly defined which should help relieve the "dead end" syndrome. Job-based performance tests would be used to assess the individuals' progress. Written tests would be used only when retained knowledge of principles, concepts or procedures was important to job performance (e.g., beginning at Skill Level II with more emphasis at Skill Level III).

4) Intermediate assessment points are included which provide for identifying exceptional, highly motivated performers who can be channeled into accelerated training paths to achieve early utilization of available resources. A corollary is a provision to identify individuals whose performance is inadequate and to provide for referral to remediation programs or for reassignment.

5) During this first 30 to 45 days on board ship, the individual will be assigned to an Indoctrination Division, with a division officer (master/senior chief) oriented to the needs of new sailors. This allows for early peer group identification which should sustain the individual until he or she is assigned to a career division during the latter part of At-Sea Orientation. Assignment to the mess decks is an acknowledged part of At-Sea Orientation. Most all individuals would participate, but only once.

6) Both vertical and horizontal progression paths are provided on the basis of measured interests and abilities. Vertical progression involves the main career path and stresses increased knowledge and technical skills. This path includes shorebased technical training. The horizontal path is designed for those individuals who can advance to greater responsibility, through job enlargement or redesign, while maintaining essentially the same knowledge/skill level and supported by job performance aids.

7) Shorebased and shipboard training are treated as one training system with the advantages of each emphasized. Instructional techniques such as exportable training, self-study techniques, non-resident training, "self-directed" training concepts and associated management solutions will be employed on shipboard using existing systems, personnel, and equipment. This program will be closely coordinated with the more formalized training curricula to be provided at shorebased schools. The model includes the conception, development and test of a shipboard training management and administration system which will be tested as a part of this study.

8) The attempt was made to fully utilize job performance aiding technology including such rather new innovations as hybrid and enriched aids. It is through aiding that we get the individual on the job early and contributing direct-

ly to equipment maintenance. This early "hands on" experience is intended to promote the feeling of involvement and a sense of accomplishment.

Test and Evaluation

Plans call for the EPICS to be tested in the fleet beginning in FY80 using the NATO Seasparrow Surface Missile System as the test vehicle. An evaluation will be conducted to appraise performance increments, cost benefits, life-cycle cost implications and personnel system impact considerations where fully integrated JPA technology is employed. A JPA user's guide has been produced which assures the best application of job performance aid design criteria considering such factors as technician aptitude and experience, equipment complexity, task complexity and training/support criteria (Booher, 1978). Other products which will result from the study are job performance aids, training packages, career and training path outlines and advancement tests for the NATO Seasparrow Surface Missile System. Also to be provided is an appraisal of the life-cycle cost benefits and cost tradeoff considerations associated with JPA-based, integrated personnel systems. In addition, a detailed user's guide for system planners and developers in the optimal utilization of performance aiding technology employed with a personnel systems context will be forth-coming.

Implementation

Of course, if a personnel system concept never gets farther than a graphic diagram, its value will never be realized, regardless of its potential. Hence, an important part of any system development is implementation of the particular design selected. The number of impact areas with EPICS is obvious. They include most all the elements of the current personnel system from recruiting to shipboard quota control. One of the major impact areas is shipboard training. Although shipboard personnel may be willing to share the training responsibility with the shorebased training community, considerable aid and support is going to be required.

Actually, implementation should be considered another system design function and followed through system development. With EPICS, the implementation program involves carefully planned briefings, informal interaction with experienced shipboard personnel, the development of change intervention strategies, and the identification, training and support of change advocates on board our test ships. Implementation involves as much attention and technical effort as any other task in the system design process.

Payoffs

The implementation of integrated personnel systems such as EPICS offers an exceedingly promising avenue for addressing the goals and objectives stated earlier. It is believed that EPICS can provide considerable leverage in the maintenance training area by (a) reducing front-end-loaded training and associated costs, (b) increasing the relevance of both shorebased and shipboard training through coordination, (c) improving the quality of the student, (d) reducing shipboard maintenance costs, (e) affording better utilization of available personnel particularly those considered to be "lesser aptitude," (f) reducing attrition, and (g) enhancing overall job satisfaction with the enlisted community.

RECOMMENDATIONS

The importance of lowering the barriers to the use of a systems viewpoint when dealing with the elements of a personnel system cannot be overstressed. Such an endeavor will require the cooperation of all communities involved in personnel systems research and development.

First, practitioners of the psychotechnologies which are represented in personnel systems design and development must become more attuned to the systems approach and insistent that the result of a particular approach be viewed and appraised within the context of the total system. Usually, there are but a few primary system elements which need to be addressed to determine that the approach is indeed optimum and that no negative impacts are possible.

Workshops and element-oriented technical meetings, such as this one on maintenance training, should include representation of the other personnel system "elementalities" with which such training interacts. This might serve to develop an awareness of the potential dangers of pursuing a single element approach to system redesign. Also, it would help educate representatives of other elements.

Lastly, government and industry must somehow become more attuned to the necessity of an integrated systems approach to matters related to the design and development of personnel systems. One approach here would be to include a personnel systems module within the Logistic Support Analysis requirement (MIL-STD-1388) during hardware system design and development. Perhaps through coordination committees or steering groups, it would be possible to achieve some degree of interchange among those organizational components concerned with people-related research and development.

The Integrated Personnel Systems Approach (IPSA) presented here is but one approach to the problem of achieving and maintaining a personnel systems viewpoint. The question is not so much what model or approach to employ but how effective or adaptable it might be in a given problem situation in reinforcing the viewpoint that one must look at the total personnel system even when investigating but a part of it. With that orientation, we can begin to protect against forcing design actions which result in less than optimum use of our steadily decreasing resources. As indicated at the outset, our traditional approaches to personnel R&D must be critically reviewed and new initiatives explored. Perhaps by that avenue we can draw together a technology which will allow us to deal effectively with the increasingly difficult personnel system problems of the future.

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BIOGRAPHICAL SKETCH

Dr. Robert E. Blanchard is a supervisory personnel research psychologist at the Navy Personnel Research and Development Center, San Diego. Currently, he is directing Center research in the area of performance enhancement. Prior to joining NPRDC, he was Chief Scientist at Behavior Metrics. Prior to that he was with Integrated Sciences Corporation and Dunlap and Associates, Inc. Dr. Blanchard received his PhD in industrial psychology from Purdue University in 1959. His professional work has included human factors in weapons system design, personnel performance measurement and enhancement, and personnel implications in marine biosystems.

ASSESSMENT OF AUTOMATED AIDING TECHNOLOGY

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ABSTRACT

This paper is a technology assessment concerning future tri-service and industrial applications of automated aiding systems. The technology base is essentially available at this time, and with sufficient support by Department of Defense agencies can be substantially brought to bear upon problems of personnel productivity in military technical maintenance by 1985. Current military interest in reducing formal training and increasing on-the-job training through improved aiding techniques may receive more effective implementation through automated aiding support systems. The facilities, technical specialties and key new developments needed to permit widespread military and industrial applications of automated aiding technology are discussed. It is projected that all-digital-data approaches to military technical information will eventually be incorporated into comprehensive logistics information management systems, with tri-service cooperation and information sharing.

INTRODUCTION

Product maintainability is a matter of substantial contemporary concern to manufacturers of complex military and industrial systems. With continuing technological advances in hardware systems designs, the point is increasingly being surpassed beyond which system users cannot keep equipment operational as much of the time as required by circumstances. Frequent and costly equipment vendor supplied field maintenance is often unavoidable.

Several factors have particularly contributed to these equipment availability problems. One factor has been the recent disappearance of well-trained and experienced technicians from American industry and the military services. Many of these individuals entered the job market at the conclusion of World War II, and have recently retired. Their younger replacements tend to be more mobile and apparently attach less importance to the place of work in their life styles. Training costs have increased because of the increased worker mobility, agency, company and union policies, and other factors. Another contributing factor is the increasing hardware complexity associated with engineering progress. Large amounts of time are consumed in maintaining complex hardware systems, searching through technical manuals that are inadequate with respect to usability. As indicated by Figure 1, a modern aircraft has many repairable parts than was the case in earlier aircraft, and requires substantially more technical data for routine maintenance information support. These data specifically suggest the presence of a long-term trend of increasing system complexity, and continuously burgeoning technical data, with no evidence of relief.

1939	J-F	GOOSE	525	PAGES
1942	F-6F	HELLCAT	950	PAGES
1946	F-8F	BEARCAT	1,180	PAGES
1950	F-9F	COUGAR	1,880	PAGES
1953	S-2	TRACKER	12,500	PAGES
1962	A-6A	INTRUDER	150,000	PAGES
1969	F-4	PHANTOM	225,000	PAGES
1975	F-14	TOMCAT	260,000	PAGES

FIGURE 1. Typical Technical Manual Growth

What is now being experienced in the Department of Defense and in American industry in the system maintainability area appears to represent a general condition of reduced personnel productivity, reduced systems availability, and increased costs for maintenance, all of which contrib

ute to reduced operational capacity and reduced combat readiness.

Built-in test equipment and automatic test equipment solutions to equipment maintainability continue to enjoy substantial popularity, but cannot suffice as total solutions to equipment maintainability problems. Recent innovations in job performance aiding technology, such as the fully proceduralized job performance aids (FPJPA) and associated task analysis have been shown to offer more workable solutions than traditional technical manuals (Foley, 1978). The newer types of job aiding techniques have not as yet, however, received the amount of deployment that would appear to be deserved, and experience with these newer aiding techniques still remains relatively limited.

Given the clear and obvious contributions of inadequate technical data to current problems of system availability, it is clear that higher priorities should be established for technical data improvement programs. Figure 2 illustrates these relationships. More data are obviously

DEFECTIVE TECHNICAL INFORMATION

↓

POOR MAINTENANCE, OPERATIONS, TRAINING,
AND LOGISTICS SUPPORT EFFECTIVENESS

↓

REDUCED SYSTEM AVAILABILITY

↓

IMPAIRED MATERIAL READINESS

FIGURE 2. Impact of Defective Technical Information

needed in the area of improving job aiding effectiveness of the newer techniques such as the fully proceduralized job performance aids (FPJPA) and the functionally oriented maintenance manuals (FOMM), as well as for new technique development. However, it is being increasingly undestood that hard-copy technical data are approaching the limits of continuing refinement and that is will soon be necessary to place reliance upon other communicative media. Available expertise in the area of improving hard-copy job performance aiding techniques is still slim. Expertise in the area of interactive automated job performance aiding system development research is even slimmer.

There is an associated need for building up in-house laboratory facilities and in development of sustained contractor research programs in these several areas of research and development emphasis, so that more programmatic research efforts can be undertaken and sustained for the necessary time periods.

AUTOMATED AIDING SYSTEM APPROACHES

Automated aiding systems represent a new approach to job performance aiding technology, and the Army, Navy, and Air Force are all examining the potential payoffs of computer-based systems for replacing hard-copy performance aids. A number of alternative approaches are being developed for automated technical data presentation at this time. Among the different approaches are automated troubleshooting logic aiding systems, CRT-terminal systems for transliteration of hard-copy technical content, and general purpose computer-mediated systems that can present technical information (TI) using various types of aiding formats. Both central mainframe and minicomputer mediated varieties of this latter approach are under development at this time. Computer-controlled video disc systems are a matter of some current emphasis, as an intermediate step in the direction of data automation technology development.

At this early time in evolutionary development, automated job performance aiding systems designs are being approached in different ways. There has been some emphasis placed upon special-purpose designs for single types of maintenance, such as troubleshooting. There has also been some emphasis in the possibility of eliminating hard-copy technical data altogether, and its replacement with all-digital-data systems that will eventually be used for the entire process of technical data generation, distribution, use, and updating.

Our own work has involved both system development research on deriving performance specifications for a minicomputer-based technical data delivery device and an advanced large system design effort for an entire Navy-wide technical information centralization and management system that includes automated technical information delivery. Through the former work, we have been able to establish design requirements for a state-of-the-art system for technical data delivery by the Air Force Human Resources Laboratory (Frazier, Roth, and O'Heeron, 1978; Frazier, Roth, and Huang, 1978). Through the latter work, we have outlined a system scenario for a Navy-wide all-digital-data TI system for the Navy Technical Information Presentation Program (Roth, Frazier, and Howell, 1979). The issues and implications discussed below have been drawn from this work, particularly from the Navy work.

ISSUES IN AUTOMATED AIDING SYSTEM DESIGN

With respect to the fact that the Department of Defense has many claimants for a finite budget, it is quite possible that pressures will grow in support of restricting research and development on automated aiding systems to a few large-scale system design projects that could promise early payoffs in short-term time-frame. This kind of approach has backfired in the past, in large-scale logistics information management programs with ambitious plans but hasty implementation efforts. This particular technology is

still developmental and we subscribe to a more cautious R&D development strategy that includes concurrent laboratory and field study components, preliminary to large-scale implementation efforts. For example, the Navy Technical Information Presentation Program is adopting such an approach as we support, in preference over the alternative of piecing together hardware without clearly developed planning for the eventual total plan for technical data automation. For many industrial applications, however, inexpensive technical information preparation systems can be developed in conjunction with automated technical information delivery devices, so that implementation of data automation can be accomplished in a much shorter time frame.

The time is near at which project managers of major weapon systems will be exposed to automated aiding system concepts and techniques. This possibility suggests that one of the first substantive military applications of automated technical information systems will involve establishing an automated system in support of a specific project office. What is expected is an actual deployment of system-specific automated TI systems at the project level, and an eventual standardization process for such systems as department-wide implementation becomes a viable possibility. In the industrial applications area, applications will be more varied, with more diverse system configurations and application programming.

Since the logistics commands represent the ultimate customers for such systems, issues can be expected to arise concerning the definition of appropriate roles for the in-service computer science organizations, the human factors and training research laboratories, and special project offices for technical information systems development and management. While no recommendations concerning appropriate roles are made here, it seems evident that the logistics agencies could use greater levels of laboratory support than has thus far been the case; that continuing system enhancements could be better guaranteed by active human resources and computer science laboratory R&D programs of a more programmatic type; and that some level of centralized management of these various efforts would be important for maintaining adherence to goals.

DESIGN PHILOSOPHY

The underlying purpose of technical information is to support trainee and technician information needs. Consequently, the degree to which a particular set of technical data can do so for representative members of these populations should be the primary criterion of technical information effectiveness. From this point of view, any aiding system, regardless of medium choice should be evaluated relative to those features that contribute to technical information usability. The further extension of this point is that usability enhancement criteria should drive the overall system design.

After Chenzoff's usability criteria (1973), the technical information should be correct. The full range of users should find TI content to be understandable. The TI should be capable of being rapidly found when needed. The TI should meet the specific user's needs. TI should be current. TI should be complete. Finally, the TI should not be so bulky that it is difficult to use or to transport to the work sites used.

These usability criteria are easy to identify, but not so easy to satisfy in developing system design requirements. For example, there is no homogeneous population of maintenance technicians. Instead, a wide range of skill levels and areas of specific knowledge can be found in the technician populations. Thus, information that is complete for one individual can be found to be quite incomplete for another. Similarly, information that is quite comprehensible to one individual can be incomprehensible to another. Maintenance technicians differ in information support requirements to do a job and in the type of job aids that are useful to them.

The implications of usability analysis are that technicians have different information support needs and have to be communicated with in different ways. This premise implies a system design requirement for TI presentation systems that can communicate in these different ways and present alternative types of aiding data, so that technicians can select the information that is most meaningful and informative for the individual case. With such a system, there is also an obvious requirement for technician-system communication capabilities so that alternative forms of discourse, aiding techniques, and formats can be selected as needed.

An optimal general-purpose automated job performance aiding systems would, thus, have to be capable of multiple levels of discourse, so as to communicate to technicians of different skill and experience levels. It would have to be capable of presenting various types of job performance aids. It would have to be an interactive system, so as to allow technicians to tailor the information received to expressed needs. These requirements would appear to necessitate reasonably good quality computer graphics, for presenting such aids as maintenance dependency relationships, block schematic diagrams, wiring diagrams, locator diagrams, and illustrated parts breakdowns.

All of these requirements have to do with human factors issues and criteria for software and hardware development. In our organization, therefore, system development efforts in this area are directed by human factors psychologists and system simulation facilities have been used to confirm the degree to which application software supports the human factors requirement determinations.

The hardware and software techniques needed to support these kinds of user-oriented requirements are essentially available. The major limitation at present in the hardware area is the unavailability of a lightweight and compact flat panel display, capable of presenting complex line drawings with the desired resolution. The development of high-resolution plasma panel displays represents a viable option, although it would appear that plasma technology will never approach the resolution associated with CRT

terminals. The use of CRT terminal displays would appear to be better justified for most applications, both with respect to cost and resolution variables.

The development of solid-state memory, such as bubble memory or charge-coupled devices operating as mass storage devices is not yet sufficiently advanced to be incorporated in automated aiding systems. It would appear that for some years yet, it will be necessary to utilize digital disk technology, until solid-state and video-based mass memory systems become viable alternatives.

TECHNICAL DATA PREPARATION

No technical information delivery system can be considered usable if the data are incorrect or unavailable. These usability criteria can be satisfied only through systematic procedures for technical data preparation, technical input by well-informed engineers, and hands-on verification of the data. It now appears that the technical data preparation procedures and practices represent the main challenges in automated technical information system development.

Figure 3 outlines processes and flows associated with a hypothetical technical information preparation system approch, such as the Navy might establish if it were decided to adopt an all-digital data technical information approach, as opposed to other alternatives now under consideration. The necessary TI preparation system would, first of all, require the establishment of new military standards and specifications that would be more appropriate to generation of automated TI. These standards and specifications would then have to be translated into specification compliance software that could empirically test TI contractors' data against compliance standards.

A digital data base would be prepared for the engineering data on the hardware system. It would then be subjected to analyses concerning establishment of initial requirements for user TI needs, given the prevailing maintenance guidelines and philosophy. The actual production of TI could then be undertaken using a specialized TI preparation system with associated application software. Contractor validation of TI content and correction of deficiencies could then be accomplished, again using the specification compliance test software, and through using representative technicians for test purposes.

The buying activity could then schedule TI usability analyses, employing larger numbers of technician test subjects, as a condition for acceptance of the TI product. The prepared TI in final acceptable form could then be archived for subsequent distribution.

Such a system outline implies Department of Defense provision of either applications software or even complete TI preparation systems to contractors as government-furnished equipment.

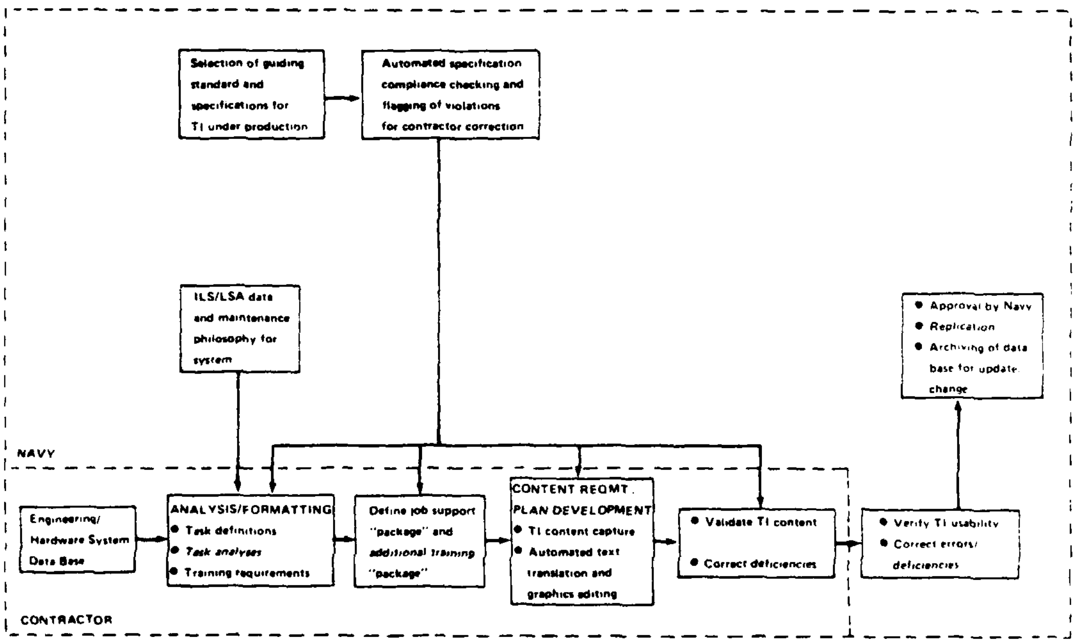

FIGURE 3. Processes and Flows in Preparation of TI in An Automated System

The [illegible] system that might be developed by a logistics command could vary in some particulars from the generalities suggested here. However, it is clear that a substantial amount of human factors input and study would need to be added to the current types of front-end analysis employed in technical information preparation programs. A substantial amount of application software would also be needed to take full advantage of modern data automation software techniques. If and when logistics agencies undertake the task of developing modern data automation facilities, it will be interesting to determine whether they fund the human factors and software development requirements identified, or whether they will simply accept the prevailing techniques used commercially and ignore the human factors work that should be added to the front-end analysis process to maximize TI usability.

With respect to specific development requirements for a state-of-the art system for automated TI preparation, the next figure represents a point of view.

The computer thesaurus requirement pertains to establishment of a technique for converting technical writer or engineering language into discourse more suitable for use in system communications with technicians.

The graphics and textual information can then be integrated under the control of format control software, using the engineering data to be communicated via engineering data base software. The TI data base software can thus be created, and checked for compliance with governing specifications. The draft TI package can then be stored for further evaluations.

Development of such a system would be no trivial undertaking, but one which could certainly be undertaken at this time. The product would hopefully be suitable for tri-service as well as for contractor purposes.

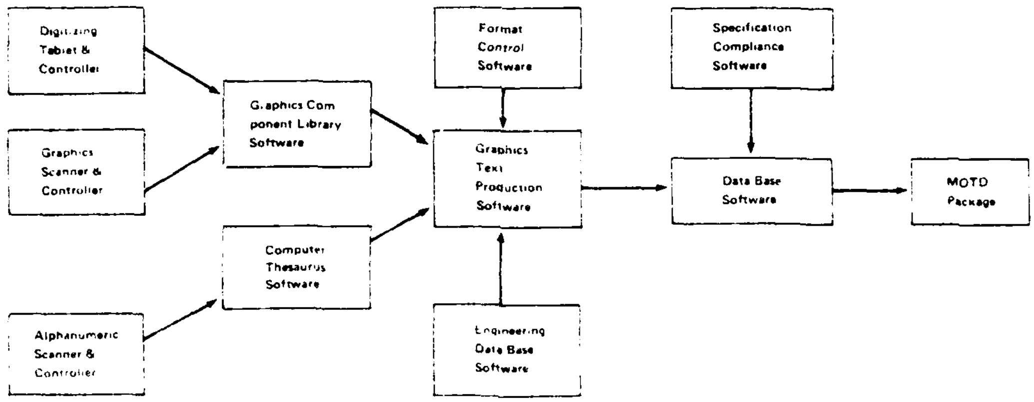

FIGURE 4. Key Development Area Requirements for TI Preparation System

For the capture of graphics and alphanumeric data, digitizing tablets and alphanumeric scanners are used at this time. There is no commercially available graphics scanner that can automatically convert graphics information in the form of line drawings into digital vector information as far as we know. The Army is funding a development effort on this problem at present, although the project is still in an early phase of development.

The development of a graphics component library and associated software would allow reccourse to contemporary interactive graphic production techniques, which are limited at this time primarily to university computer science laboratories. With such a library and suitable TI preparation system, it should be possible to construct complex illustrations rapidly and with minimal cost, through interactive retrieval, scaling, and positioning of standard graphic components and graphic assemblies, and to store the finished graphics in computer storage to await integration with textual data.

IMPLICATIONS

It will obviously take some years and first-rate human resources to develop fully operational all digital data TI systems for service wide and contractor generation, testing, distribution, use and updating. Efforts of this kind must be approached carefully and sustained for some years, both with respect to special project offices and cooperating contractors. The technology is new and evolving rapidly, with a scarcity of available expertise. However, it seems equally possible to realize near-term payoffs of technical data automation that can impact significantly upon the basic problems of operational capabilities and system availability for specific weapon and industrial project offices.

What easily could result would be a concurrent development and implementation process, in which logistics agencies incrementally build capabilities for technical data automation, and project offices introduce automated TI systems for their own system projects. At some point in

the future, these concurrent developments could merge into service-wide and industry-wide TI data automation systems that service TI user needs on a general basis.

Early evidence of a new trend is also emerging from the administrative information processing area. End-user oriented administrative system designs are now beginning to be taken seriously and several federal civilian agencies are now designing nation-wide administrative job performance aiding systems. These efforts apparently have been undertaken independent of any communication with the Department of Defense technical data community, suggesting a Zeitgeist that is increasingly supportive of computer aiding systems for humans. Some level of cross-fertilization would appear to be likely between these hardware-oriented and administration-oriented agencies.

Another trend that may impact upon the evolution of automated job performance aiding systems is the home computer market. This market has already become sufficiently large that major computer manufacturers are entering into it. The current orientation remains that of marketing computer games, but with some small and increasing emphasis upon computer-assisted instruction applications. What could be predicted after automated job performance aiding systems are popularized is the development of a brisk market for the sale and distribution of aiding and training packages for special-purpose home computer configurations.

It is difficult to project the rate at which these different applications will develop. It would seem quite likely, however, that the industrial, administrative, and home applications will all be well developed and will be enjoying a viable market within five years. The military applications could be enjoying some significant level of implementation not long thereafter. However, decisions to adopt the so-called intermediate solutions such as computerized microform and video disc systems could delay this development by at least another five years. Thus, large-scale military implementation of all digital data technical information systems could be postponed until well into the 1990's, depending upon the decisions made at policy and planning levels and at logistics agency headquarters over the next several years.

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BIOGRAPHICAL SKETCH

Thomas W. Frazier, currently Executive Director, Behavioral Technology Consultants, Inc. Principal investigator and program development officer. Formerly with Johnson Space Center and Walter Reed Army Institute of Research. Ph.D. in psychology from Florida State University. Research background in human performance decrement and enhancement, behavior stress and conditioning and learning theory.

ON-THE-JOB TRAINING AND AIDING: THE ARMY'S SKILL PERFORMANCE AIDS PROGRAM

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ABSTRACT

One of the oldest and most frequently used methods of training personnel is on-the-job training. The Army has had to rely on this method to transfer specific skills and knowledges to the soldiers who have received only broad principles and skills training in a formal classroom setting. There are inherent weaknesses to the on-the-job training method, however, which detract from its overall usefulness in improving individual soldier proficiency. Lack of adequate training materials, lack of equipment, and little or no diagnostic measures are examples of such deficiencies. The advent of fully proceduralized technical manuals has presented a unique opportunity to remedy these weaknesses. The Army is seeking to obtain the maximum benefit of the proceduralized manuals in its Skill Performance Aids program. An on-the-job training package is developed for each equipment system that uses the manual as the prime instructional material and attends not only to the needs of the inexperienced soldier but also to his supervisor as well.

INTRODUCTION

The Department of Defense continues to seek to provide the best possible defense system that can contain and repel any military threat. As in the past it turns toward hardware technology advances as the chief method of insuring our superiority. Again, as in the past, it must use other means as well if it is to offset the numerical advantages and increased technological capabilities of foreign powers. One such means is training which has frequently spelled the difference between success and disaster. The improvement of training, while always a goal, has been gaining in national interest as well as controversy. The obvious interest has come because everyone recognizes the need to be in a continual state of readiness to meet the possibility of a rapid attack. The first battle has taken on extreme importance. The concern of the US Army for maintaining readiness is shown by an increase in testing of both units as well as individuals. Moreover, this testing program has been intently aimed at measuring proficiency on the actual tasks that our Army will have to perform in the event of war. The results, as you may well expect, are not always gratifying and point out the need for better training to improve performance. At the same time materiel readiness reports continue to point out equipment problems, some of which are directly attributable to problems in human performance.

The controversy arises over the various strategies that we should employ to overcome these deficiencies. At the center of the controversy, as you would expect, is the dollar. No longer can we be concerned with only training effectiveness but we must be concerned with efficiency as well. As a result we see elaborate models being constructed that seek to optimize our training investments. New methods of instruction are being explored that include the use of automation for both presenting and controlling instruction, the use of self paced courses that include audio and audiovisual media and a general trend toward insuring that all such instruction is criterion referenced. The controversy arises in not only selecting the approach to be used but also in deciding how much training should be given.

The answers are far from being clear, at least in part, because we have yet to obtain a consensus on what the problem is. Therefore before I describe one of the Army's present solutions I would like to describe first what problem that solution is intended to alleviate.

The Army is increasing in its mechanization averaging .71 systems per man, not including individual small arms. The systems have also become much more sophisticated in terms of capability and accordingly in terms of components as well. No longer do we have the luxury of specializing individuals on any one system at the training schools. A single specialty such as a 63C track vehicle repairman can potentially encounter any one of more than a hundred vehicles. Obviously, trainers at the school can only teach general principles and techniques and then hope that as the individual soldier receives on-the-job training and gains in

experience that the will be able to cope with any problems that he encounters. The problem has been that this approach when used in the past has left something to be desired - as indicated by our tests and materiel readiness reports. Adding more formal training has not been an adequate solution because of the evidence of learning decay and the unpredictability of future assignments. The cost of such training, in light of the rising personnel costs for salaries, benefits, etc., and the normal high attrition rate makes additional formal training an option that we cannot afford. Yet the Army does recognize that additional training is required. The Army's Skill Performance Aids (SPA) Program is one attempt to increase the level of individual proficiency without drastically incurring huge training costs. This paper reports on the development of this program.

THE SPA PROGRAM

The Skill Performance Aids Program consists of improved technical manuals and extension training materials that are developed on the basis of a common front-end analysis.

Improved Technical Manuals

Beginning with the PIMO Project (Foley, 1978) in the early Sixties the potential capability of fully proceduralized technical manuals to improve human performance gradually has been recognized. In the Army these types of manuals are becoming institutionalized and new systems and selected fielded systems are being supported by this approach. The process of institutionalization has not been easy and indeed SPA still invites skepticism because of the additional cost and time associated with its development. Despite the consistent positive results obtained in experimental settings critics argue that similar results will not be achieved operationally because the manuals will not be used or will not be used properly. Moreover they fear that the availability of such manuals will be used as an excuse to wipe out all formal training and that complete dependency will be placed on the manuals.

The Army Approach. The Army has quickly recognized that some degree of initial formal school training will always and should always be required even with the presence of fully proceduralized manuals. The emphasis of this initial training is on providing generic skills such that the individual can then learn the specific tasks associated with his job. The manuals, therefore, while proceduralized do not contain details as to how to use a particular hand tool or piece of test equipment. They do provide details specific to the particular piece of equipment. Thus the 63C repairman will have been taught how to repair a section of track on a tank but not on all tanks. The manuals will describe the location of items and the order of steps to be followed for a particular tank. The design of the manuals is well documented and need not be repeated here (see for example the JPA Technology Workshop Proceedings, Human Factors Society, 1977). The Army is convinced that these manuals are required. It differs from the other services in that in addition to performance enhancement it finds in these manuals a unique opportunity to create a uniform effective on-the-job training program.

Implications of Improved Manuals for Training. Conventional manuals which have been equipment descriptive have not provided the details needed to support the soldier in training. The TRADOC schools have had to generate a considerable amount of equipment specific training materials to teach these details to the soldier. Since the majority of these items do not accompany a soldier to his unit, the soldier finds himself in a new job with manuals that are too difficult for him to use. In the SPA approach the fully proceduralized manuals are the primary resource for the training of equipment specific tasks. All that is required is an adequate management scheme for the use of the manuals in on-the-job training and some supplementary training materials for tasks that are particularly difficult.

Extension Training Materials (ETM)

ETM are extensions of the technical manual for selected tasks which require instruction beyond that which is presented in the manual.

Task Selection. The initial analysis of equipment which identifies the total task list and provides task details is performed during front-end analysis that is described later in this paper. During the ETM development process each task is analyzed with appropriate head-book trade-off decisions made explicitly. If the task appears straight-forward with no particularly unique requirements then the decision can be made to rely entirely on the proceduralized manual with no further consideration being made for training i.e., the skills required to perform those procedures are already in the soldier's repertoire (as a result of his formal training). Other tasks do require training. These are generally of two types: those which present a degree of learning difficulty (e.g., difficult motor, sensory or judgmental skills) and those which require immediate task proficiency without reference to the manual (e.g., operator tasks and emergency procedures). The resulting task list is then screened to group those which require a common skill e.g., use of a special tool. These may be combined or reduced in scope in the lesson approach.

Design and Development. The lesson and course design and development is performed following the Interservice ISD Model. Particular attention is given to the development of standards that will be explicit to both the trainee and his supervisor NCO. Both process scoring and go/no go end item scores are utilized in the criterion referenced tests to provide the maximum amount of feedback without tying the NCO down to one individual for extensive periods of time. Early validation trials are used to determine not only if lesson objectives are achieved but also to determine if field objectives can be achieved, i.e., the training managers guide is validated as well to insure that equipment demands are reasonable or to determine if special trainers are required.

ETM Training Packages. A training package is prepared for each specific equipment item. It contains all of

the instructions and materials necessary to support a supervised on-the-job training (SOJT) program for a particular MOS and maintenance level. Each ETM package contains two basic documents; a Manager's Guide and a Student Guide. The Manager's Guide provides the NCO with complete instructions and recordkeeping aids to conduct the program. The Student Guide provides general instructions concerning that ETM package and specific lesson applications for the Soldier, and also includes pre-tests and post-tests. Lessons may be in one of three modes of presentation: Printed Text, Audiovisual (AV), or Audio-only (AO). The printed medium is the preferred method of lesson presentation for reasons of both economy and ease of use in the field. When justified by training effectiveness considerations, the other modes may be used. The lessons are designed to permit the student to perform much of the lesson by himself. The NCO is involved at critical checkpoints throughout the lesson. The checkpoints are defined in the lesson instructions.

ETM Scenario. The NCO, in concert with the Soldier, selects an ETM lesson. This selection will be based upon unit and individual needs and guided by the lesson sequence instructions. The NCO has the Soldier read and become familiar with the Student Guide and basic technical manual. The NCO then administers the lesson pre-test to the Soldier. If the pre-test is passed, the NCO annotates a "GO" in his Course Record Sheet, and the lesson selection process is repeated.

If the pre-test is a failure, or "NO-GO", the NCO administers the lesson to the student. By virtue of its design, the NCO will not have to be present during the entire lesson, except at those points so stated in the lesson instructions. After the Soldier has completed the lesson, the NCO administers the post-test. If the post-test is passed, the NCO will indicate the "GO" in his Course Record Sheet and the pre-test, lessons and post-test procedure is repeated until the Soldier completes all of the lessons in that ETM package. If a post-test is failed, then the NCO will administer remedial training according to the lesson, which will include any supplementary materials suggested as additional training materials.

The NCO can now use the Course Record Sheet as a quick reference guide to identify those areas of weakness for future training needs. The Course Record Sheet is kept by the NCO until the Soldier departs the unit. At that time, the record would be transferred to the gaining unit to certify the Soldier's OJT progress, and equipment knowledge.

Front-End Analysis

Regardless of "format" used the most successful innovations in technical manuals and training have all been based on a comprehensive analysis of the job and individual tasks prior to preparation of materials. The Front-End Analysis used in the SPA approach utilizes a common data base for the TM's and training. Data are collected relevant to the equipment to be maintained and the personnel expected to use the materials. Typical "products" include a complete task list which is structured according to the job which is to be performed i.e., operator, organizational maintenance or DS/GS maintenance. A tentative list is made of user prerequisites such as aptitude scores, reading grade level, skills in performing basic maintenance procedures and basic knowledge of certain principles taught in the formal school setting (such as fundamentals of electronics). Each individual task is then described and analyzed resulting in a collection of task details shown in Table 1.

TABLE 1. Task Details

Equipment Condition	Task Interval
Tools and Test Equipment	Hazards Criticality
Preliminary Tasks	Follow-on Tasks
Hazards	Auxiliary Equipment
Task Standards (Time, etc.)	Supplies and Forms
Environmental Conditions	Major Task Steps
Coordination Requirements (verbal, time, physical)	

It should be recognized that the above task details are useful for both the ETM and manuals. Most of this information will be included in the technical manuals directly but was also necessary for training decisions and development of lessons. In the past such detailed analyses were conducted for training purposes; however once the essential training information was obtained the information only found its way into training manuals and was not used on the job or it was discarded completely. The technical manual developers performed their own development sequence but in an unstructured process that was not usable by training developers. The SPA approach eliminates or at least greatly reduces this costly duplication of analysis and, more importantly, insures that all tasks are adequately covered by either the technical manual, training or both. In the past incorrect assumptions were made by both the manual developer and the training developer because responsibilities were assigned only at a global level. These responsibilities are now explicitly stated at the task level.

DISCUSSION

The inherent power of the SPA approach lies in its total commitment to the systems approach. Each of the concepts found within the SPA program have succeeded on their own merits; yet taken alone these concepts have not been used to best advantage and have come under attack if for no other reason than cost effectiveness. Conducting a detailed task analysis for training purposes, only to discard the information because only principles training can be afforded, is not cost effective. Developing fully proceduralized aids for overtrained individuals (if it were possible) is likewise not cost effective. To rely on the traditional on-the-job-training concept is not effective for many reasons as pointed out by McGehee and Thayer (1961). No diagnostic measures are generally available, the training can be very expensive if special materials and special instructors have to be provided, or the training can be totally ineffective if no materials are provided and the trainee

"learns-by-doing" on very expensive equipment using trial and error methods. It likewise places an undue burden on supervisors to create their own training programs when the majority of them do not possess the time or proper training to create such materials. The SPA program integrates these concepts and for the first time makes available a supervised structured on-the-job training program that adequately supports both the soldier and his supervisor and provides comprehensive performance aids to insure that proficiency on the job can be maintained.

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ABOUT THE AUTHOR

John Klesch is currently assigned to the Developing Systems and Training Devices Directorate of the US Army Training Support Center where he is a Branch Chief of the Skill Performance Aids Division. He has been involved in both the research and application of job performance aids in the past 9 years.

"TRAIDING" AND THE MERGER OF TECHNOLOGIES

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ABSTRACT

This paper first outlines the two areas of training and aiding, which have remained as relatively distinct entities for several decades. Problems generated by such separation are discussed such as the development of aiding materials which are so specific that the technician is left in a dead-end career slot, and maintenance simulators which teach only hands-on practice without any form of verbal material to tie the overall task together. Finally, the possibility for merger in the form of "Traiding" is proposed.

INTRODUCTION

The training and aiding communities have been "separate but equal" for so long that many of us have been slow to notice how closely intertwined our destinies have become. So closely, in fact, that one day the second author's eyes became slightly crossed from fatigue, and they accidentally conveyed the word "traiding" to him; it seemed so natural that he didn't even slacken his pace, but resolved to work this fortuitously conceived concept into a conference.

THE WAY WE WERE

The functions of training and aiding grew up (or at least reached adolescence) separately, because of an accident of history: training came first and was firmly entrenched by the time performance aiding matured enough to be considered "a technology." Even though many of the performance-aid pioneers and their descendants were training types, they had their own rats to kill, and for the most part were forced to design their experiments and mold the elements of their technology in something of a vacuum.

Meanwhile, the pressures of the "systems approach" led the training community to become heavily absorbed in development of the principles of Instructional System Development (ISD). The ISD people and the performance-aid people still spoke the same language, and even espoused roughly the same "front-end analysis" approach, but when it came right to the point of sitting down and working together, the closest we got was the rather standoffish concept of "the head-book tradeoff." The latter presented at least a theoretical opportunity for both groups to participate in the explicit allocation of tasks to training, documentation, both, or neither. But neither group incurred an obligation to the other to follow through and make certain, as the training and aiding development continued, that the combined final product would be good, or even that it would work at all.

It became obvious from even the early applications of ISD and performance aids that there were a number of serious loose ends which had not been addressed by the developers. In all the services, these loose ends seemed to have devastating consequences for the implementation and acceptance of programs, as well as for the long-range well-being of job incumbents. On the training side, simulation technology (at least for flight training) outstripped our ability to figure out how to use simulators effectively, and large, expensive devices were purchased, only to be used inappropriately or not at all. In this regard, maintenance training simulators have been fabricated which teach hands-on troubleshooting skills in a truly effective manner, however, without any form of verbal presentation to accompany the device. Thus, the self-paced possibilities of the equipment are almost totally neutralized.

On the publications end, self-instructional material was prepared in formats that offended users and consequently fell into widespread disuse. Inadequately-prepared instructors took unfamiliar state-of-the-art material and converted it back into the same only stand-up lecture drill.

And experimental students, taught how to do complex jobs without knowing the theory behind them, found themselves up a career stump. There was no upward career path for someone who could merely do the job competently--tradition dictated that he also be able to pass advancement tests involving theoretical material not necessarily relevant to the job. The experimenters had not been at liberty to alter the advancement scheme or the career structure, and it became immediately and painfully apparent that another family of "moderator variables" had been identified.

Performance-aiding, insofar as it has been developed to date, has largely evolved as a subset of publications. As such, aiding went through all the same mistakes as the above, with all the same consequences. Improperly or incompletely introduced aids were resented and went unused. Experienced maintenance people found some proceduralized aids cumbersome to use, tried shortcuts, and attributed lack of success to the aids rather than the shortcuts. And again, the entry-level trainee for whom some of the "idiot-level" aids were designed discovered that he would be in a dead-end career slot as long as he was dependent upon the aids, because we hadn't even thought through the problem of what to do with him if he turned out to be career-force material. We tried to sell advanced aids on the grounds that they offered the chance to defer expensive front-end training until later and to get useful work out of people very early in their first enlistments. We demonstrated the useful-work-early feature but forgot to design the training-deferred-to-later feature, leaving experimental subjects stranded in a partial-prototype limbo.

Although our limited tryouts in aiding, as well as those in simulation (especially maintenance), were generally successful in demonstrating the particular phenomena under investigation, each time we expanded the scope of an experiment, we discovered more "moderators" that we had overlooked or failed to control. Having catalogued more serious oversights, we resolved to manage most of them more carefully when we finally got our first chances for large-scale, real-world implementation. The stage was finally set for attempts to tie training, aiding, and moderator-wrestling together into a coherent approach to building and maintaining competence on the job.

WE'RE READY FOR TRAIDING

The Army's Integrated Technical Documentation and Training (ITDT) program (now called Skill Performance Aids (SPA), and discussed elsewhere in this volume by John Klesch) has had its ups and downs, but it is the first really broadly applied attempt to control both training and aiding development centrally, using an ISD-type approach. It is ironic that although training and aiding are being developed centrally in SPA, the main thrust of the program is to de-centralize technical training overall.

Also discussed elsewhere in this volume (by Bob Blanchard) is NPRDC's new Integrated Personnel System Approach (IPSA) project. The first author's bias is that the IPS approach will be somewhat more flexible than that of the Army's SPA in terms of one's ability to tailor the solution to the problem. Although the IPS project began in the context of performance-aid research, it is designed to arrange for control over the entire personnel system, including the design of jobs, and specification of a new occupational specialty if necessary. If a new career structure spanning more than one enlistment is required, detailed training and aiding plans are designed to foster the dynamic shifting of the head-book tradeoff across an individual's enlistment.

If the personnel pipeline management levels of IPSA at NPRDC could be married to some of the instructional delivery schemes of the Human Factors Laboratory, Naval Training Equipment Center, it is the second author's bias that a powerful combination could result. And if this could be leavened with healthy doses of decentralization from Army's SPA, perhaps Traiding could really fly.

One point seems certain. Compared to the provincialism of the past, the long-term, dynamic adaptability of training and aiding to the changing needs and capabilities of the technician is probably the most important feature that a new Traiding concept should have. Many operational environments have job slots for people of more than a single skill level within a given specialty, implying that someone in there is not yet a journeyman, and that we expect him somehow to increase in competence as he matures in his job. We have traditionally treated both training and aiding as stationary targets, and have made assumptions that resulted in our taking a single, very large shot at the front end. Traiding must recognize that the technician will evolve (whether we wish it or not) into a slightly different target every day throughout his enlistment, and that evolution rates and asymptotes will vary across individuals. It's a bit like tumbling rocks in order to polish them. If you just want to knock the rough edges off, you can use a pretty coarse polishing compound. But, if you want to bring each piece to a high polish while allowing it to retain its own unique shape, you have to commit yourself to using a carefully planned sequence of compounds that differ from each other both in coarseness and in composition.

WHAT DOES THE "TRAIDER" DO?

The Traiding approach will ultimately have to provide a catalog of polishing compounds so that program managers (Traiders) can choose an acceptable match between their pocketbooks and the size of the odd-shaped nooks and crannies that they want to polish. We may even have SPA, IPS, JPA, ISD, simulator design, and job design specifications to comfort the program manager who wants to build state-of-the-art maintenance performance and job satisfaction. But there is one more important ingredient missing: guidance in how to be the ideal program manager. We've all seen (and some of us may have helped to create) the problems faced by a program manager as he tries to juggle the components of a system. The Traider will, if he survives, have to develop a manager's handbook

that would include chapters on how to avoid the influence of lobbyists, how to get the whole team working together (possibly by having some of the training developed by the tech data people and some of the tech data developed by the training people), how to be sure the products are complete and accurate, how to implement the whole thing in such a way that it will be used as intended, how to be sure new concepts of training devices, simulators and other media are used in an effective way, and how to evaluate the new system to be sure it is providing the intended results.

The ISD process has been around long enough to demonstrate to most of us that including it (ISD) in a program spec doesn't ensure that its spirit will be reflected in the final system. If the program manager can be buffaloed by contractors, members of his own team, or the training establishment, some of them will probably try to cut a few corners, quite possibly subverting much of the ISD philosophy in the process. The successful Traider will need an unfailing combination of clear guidance, measurable criteria, and stern resolve to keep all of the elements communicating with each other, and meeting those criteria.

LET'S TRAID

Some of the participants of this conference have assembled for similar reasons in recent years, and each time, they have brought along increasingly fine-tuned training and aiding concepts and techniques, and increasing awareness of the real-world concomitants of Traiding as we mean it here. We are finally engaged in some extensive, ambitious projects that can reasonably be thought of as prototype Traiding projects. The lessons that we stand to learn about implementation of Traiding should put us in a strong position to move ahead with a DOD-wide program of improved and workable maintenance training and aiding.

BIOGRAPHICAL SKETCH

Mr. Reid Joyce

Mr. Joyce joined Applied Science Associates, Inc., in 1967 after receiving his Masters in Experimental Psychology from Michigan State University. At ASA, he has conducted a number of studies of advanced job performance aids and technical training. He directed the development of a military specification (MIL-J-83302) for performance aids, and several handbooks for performance-aid developers and Air Force program managers.

He is currently directing a study of on-the-job information-seeking behavior by Army maintenance technicians, and is working on the long-range test and evaluation plan for NPRDC's Integrated Personnel System project. In his "spare" time, he is a certified SCUBA instructor, an instrument-rated pilot, and builds experimental aircraft that he flies upside-down intentionally.

Dr. William J. King

Dr. King, a former Remote Control System Technician in the U.S. Marine Corps, obtained the B.A. degree in Psychology from the State University of Iowa, the M.A. in Experimental Psychology from the University of Illinois, and the Ph.D. in Experimental Psychology from the University of Sydney, N.S.W., Australia. In the Human Factors field for over twenty years, Dr. King has worked with the man-machine problems of many types of military vehicles such as submarines, conventional aircraft, helicopters, and space vehicles. He has authored a number of Technical Reports and publications, and is now employed as an Engineering Psychologist in the Human Factors Laboratory, Naval Training Equipment Center, Orlando, Florida.

THE AUTOMATED INTEGRATION OF TRAINING AND AIDING INFORMATION FOR THE OPERATOR/TECHNICIAN

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ABSTRACT

A responsive and intelligent device which can provide both training information and job performance aiding can be extremely efficient in utilization of hardware, software, and so-called *course-ware*. The hardware components useful for presenting automated instruction are essentially the same as those required to aid an operator or technician, viz., a versatile and fast microprocessor CPU, ample random access memory, ample bulk storage, and appropriate input-output media. While the software driving such a device may be a collection of relatively special-purpose routines designed to satisfy particular training or aiding needs, a large portion of this software may be common utility functions which respond to specific requests of the user or serve to manipulate data about the target equipment or data about the operator/technician. Finally, the data base which characterizes a target equipment can be designed in such a way that both training and aiding requirements are met without duplication or inefficiency of preparation effort.

Under a contract with Naval Training Equipment Center, Behavioral Technology Laboratories has assembled the hardware elements of such a system, designed the data base structure for characterizing a specific target equipment, and programmed routines for training novice operator/technicians and aiding equipment operation and maintenance.

BACKGROUND

There has been much discussion and disagreement over the years regarding which requirements for technician proficiency are most appropriately *trained* and which are better provided via external job performance aids. It appears that no static and definitive assignment process is forthcoming, for the environment is complex, rapidly changing, and difficult to specify. These harsh realities do not diminish the need for the curriculum designer to make rational choices in determining what components of performance critically require training. They do, however, create a need for a technique to deliver appropriate assistance to the maintenance technician at the job-site and to provide additional training to that technician so that his future dependency upon the support system is reduced.

Such a technique is especially attractive if the resources required to deliver job support are essentially identical to those required to provide training. This Laboratory, under contract to Naval Training Equipment Center, has been developing a computer-controlled trainer/simulator/job support system, with an emphasis on utilizing common hardware, programs and data base to meet needs ranging from OJT to detailed job performance assistance.

The system, called AIDE (Automated Instruction, Direction and Exercise), is controlled by a general-purpose monitor program which extracts and combines information from a data base containing specific content. The monitor and data base structure share generic maintenance concepts, such as controls, indicators, malfunctions, functions, symptoms, etc. A new target equipment can be implemented on AIDE by preparing an appropriately formatted listing of control names, settings, indicator names, possible symptoms, functions, malfunctions and so on, plus a set of graphic aids.

AIDE, therefore, consists of hardware to process data and interact with the maintenance technician, a computer

program, and a representation of the target equipment, the first two of which remain fixed over different applications.

OBJECTIVES

The primary objectives of our work have been to 1) assemble the hardware elements necessary to deliver various configurations of OJT and JPA, 2) formulate a data base structrue which can be "filled" by a technician who is an expert only in the maintenance of a particular system or device, 3) design a complete computer program which can interact intelligently with a technician to satisfy a wide range of needs, and 4) implement the designed routines, along with a sample data base, to test and demonstrate the capabilities achieved.

The program design includes provisions for adapting to an individual's level of proficiency and experience. This becomes quite efficient, in fact, in a combined OJT/JPA system since many of the technician's training requirements can be detected when he requests assistance during performance of a job task. Conversely, the job support offered can be more easily tailored to the individual's needs when the assisting system is the one which provided the training to that individual.

It is difficult to characterize the instructional approach employed during the instructional phases in terms of any one well-known technique. AIDE acts somewhat Socratic (Collins, 1976) in the sense of responding to user-initiated requests. It also is heavily oriented to what Norman terms web learning (Norman, 1976), i.e., initially providing a gross, fundamental structure of knowledge about a topic which is successively elaborated with increasing detail and wealth of information. For performance aiding the system functions primarily as an information retrieval system, with the advantage that both data base structure and retrieval functions are consistent from one application to the next, and are not the responsibility of the content expert implementing a new subject equipment. Thus "generative" approach (Rigney and Towne, 1974) allows the content expert to concentrate on describing the target system, without being required to also formulate student-computer dialogue, instructional schemes, etc.

OJT-JPA CONTINUUM

We recognize that few performance requirements will always be satisfied via training, or always by performance aiding. Further, it appears that "pure" (exclusive) training and "pure" performance aiding are rare occurrences; most training experiences involve some degree of job support, and most supported performances rely on some degree of previous training. Thus the appropriate level of training and job support to provide a technician becomes knowable only when a particular technician is to maintain a particular equipment or system, in some defined, and probably somewhat unique, environment.

Obviously, as a technician receives increasing training he is able to independently generate more of the required actions and decisions which would otherwise be supplied via external aids. A major goal of a training/aiding system, then, is to determine where a particular technician stands on this continuum, shown in Figure 1 (Rigney, 1976) and to supply the appropriate job assistance.

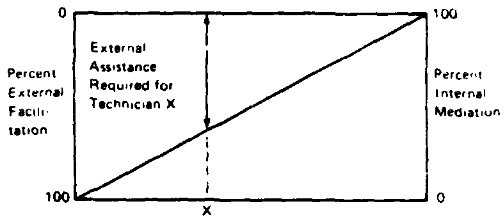


FIGURE 1. External Facilitation vs. Internal Mediation

Table 1 presents a summary of the types of requirements for JPA and OJT which AIDE addresses and the variations in technician familiarity which are accommodated. It is emphasized, however, that the user may access any of the available support or training capabilities, regardless of his proficiency, if he so requests.

AIDE HARDWARE

The major hardware elements of AIDE are as follows:

1) a small computer (microprocessor CPU random-access memory and mass disc storage)

2) a 9-inch CRT: displays words, lists, names, etc.

3) a micrographics unit: displays color photographs under computer control - can be either 35mm random slide projector or color microfiche unit.

4) a sonic touch-pen: for user inputs

5) a small hard-copy printer

6) a voice synthesizing device.

Figure 2 is a view of AIDE as seen by the user. The command memu is simply a removable card labelled with the commands to which AIDE will respond when touched by the sonic pen. These commands allow the user to:

1) Select mode of interaction (assistance, instruction, drill)

2) Obtain any available information about the purpose, theory of operation, or location of a section of the equipment

3) View either a photograph or functional diagram of a section

4) Exit AIDE.

Technician Familiarity with Particular Equipment	Needs for Performing Job (JPA)	Needs for Learning (OJT)
None	Detailed task specifications with graphic aids for locating and identifying system elements	Basic drills in recognizing and locating system elements
Some (Can locate and recognize many system elements)	Detailed task specifications with on demand support in locating and identifying elements	Introduction to purpose and operation of major system elements and basic physical and functional structure
Considerable (knows location, appearances, purpose and operations of major elements)	Check lists, condensed procedure listings, etc., with on demand availability of detailed specifications	1) Elaboration of purpose, structure and operation of sub elements 2) Exercises in symptom interpretation
Extensive	Easy system for retrieving check-lists, wire lists schematics, etc	Simulated maintenance problems for maintaining skills and knowledge

TABLE 1. Requirements for JPA and OJT Management

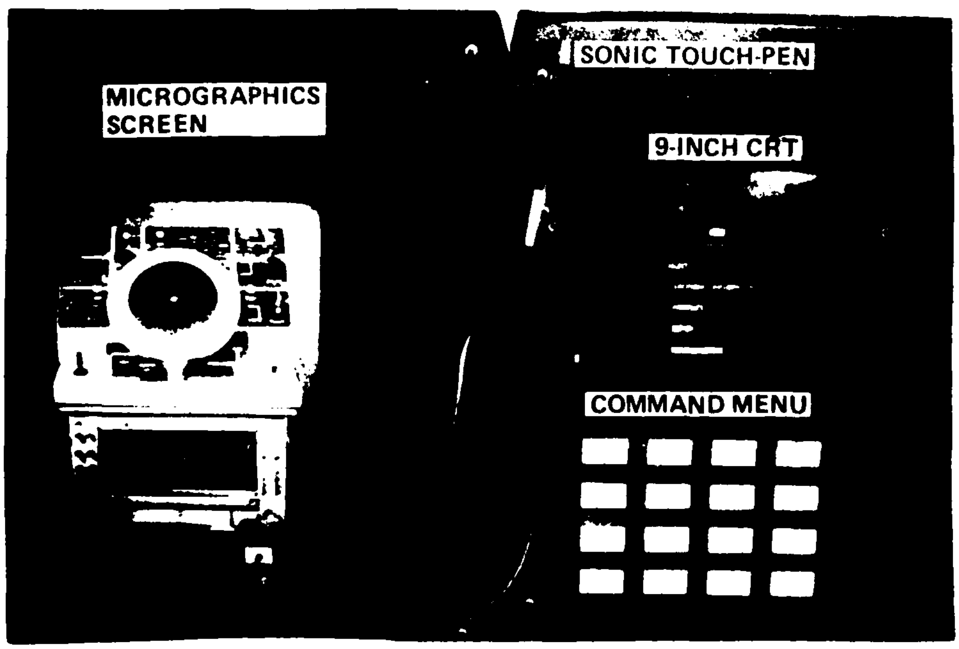


FIGURE 2. AIDE System, Front View

The majority of user inputs and responses are made by touching the sonic pens to individual items listed on the CRT or to particular portions of the hardware displayed on the micrographic screen. As described below this allows the technician to, in effect, operate, disassemble, and interrogate the simulated equipment, and to interact with AIDE regarding what he needs.

Table 3 provides further detail reqarding the hardware components each of which is commercially available off-the-shelf. This configuration was assembled to expedite development of the concept while avoiding costly and time consuming hardware integration. As expected, a number of small commercially-engineered systems have come on the market which contain the first five components shown in Table 3 (Small Systems World, 1978).

TRAINING AND AIDING CAPABILITIES

The fixed AIDE monitor program processes all inputs by the user, retrieves or computes appropriate responses, and presents the responses on the CRT, on the graphics screen, and in some cases via the voice generator.

The three basic modes of operation provided are:

1) job assistance

2) instruction

3) drill and exercise

Each of these three modes is available for each of three general topics:

1) equipment configuration

2) equipment set-ups (operating and maintenance)

3) troubleshooting

The nine resulting types of student-AIDE interactions are produced from the single bank of information and graphic representations, utilizing routines which perform such functions as:

	COMPONENT	MODEL	OPERATING CHAR. OR CAPACITY	COMMENT
1	CPU	Zilog Z-80	8-Bit Processor, 4.0 mhz	158 Instructions with 4-, 8-, 16-bit operations
2	RAM	Zilog RMB	32K Bytes	
3	Disk	Shuggart 800 Floppy	300K Bytes	77 Tracks/Disk 32 Hard sectors per track 128 Bytes per sector
4	Alpha-numeric Display	Sanyo Raster-Scan CRT	16 lines 64 char/line	9-inch diagonal screen
5	Hard copy output	Bowmar Printer	18 char/line	
6	Graphic Display	Bruning 95 Microfiche	30 fiche 60 images/fiche	1-sec. access on same fiche 3-sec. access to new fiche
7	Audio Output	Federal Screw Works VOTRAX	60-phoneme repertoire	Inflection also controlled
8	Pointing Input	SAC Graf-Pen NT-201	.01 inch resolution	Can sense 36" x 48" area; does sense CRT, Micrographics screen, and command menu.

TABLE 3. Hardware Components

1) present a picture of sub-element X

2) present text which explains the purpose of X

3) present a functional diagram of X

4) present a picture which shows where X is located

5) determine what part of X the user just touched with the pen

6) display a listing of switch settings for mode M

7) show the front panel set-up in mode M

8) show indicator I reading normal

Equipment Configuration

The most fundamental topic addressed by AIDE is equipment configuration, which concerns the abilities to 1) locate and identify physical elements in an equipment or system, and 2) understand the functions of the elements.

Instruction. A technician who wishes to become familiar with a new equipment or system would begin by entering the instruction mode, whereupon he would observe an image of the total hardware configuration. For a large system this image might be a simplified line drawing showing entire equipments as sub-units. AIDE would present whatever text is available to explain the purpose, operation, and functional organization of this entity. Next, each major sub-unit would be similarly shown and explained, all at the technician's pace.

Upon completing study of this fixed-sequence presentation, the technician may freely explore the physical system by selecting sub-elements of particular interest (with the touch pen) and reviewing whatever associated text and graphic aids he wishes. It is expected that some motivation will exist for pursuing this self-controlled study since the drill phase will require that the technician locate and identify these elements.

The sequence of drawings and photographs shown below provides some indication of how the technician can "zoom-in" from the initial overall photograph or drawing, to very detailed photographs of small sub-elements.

When the technician completes his exploration, study, and review of the physical system he progresses to a similar instructional phase related to functional organization. Then, instead of viewing photographs of hardware elements he studies functional diagrams. As before he progresses to increasingly more detailed diagrams by use of the touch pen.

Drill. Following the instructional phase, AIDE drills the technician in locating all physical and functional subelements in the system being studied. All interactions are built into the fixed AIDE monitor program such that the content expert who prepares the data base need be concerned only with describing the structure and operation of a unit in the required format.

Assistance. The current program requires the technician to search for a picture which identifies the location of a sub-unit. A planned routine to alphabetize the subelement names, display those on the CRT, and then show the image which shows the location of the selected unit has not yet been developed.

Equipment Set-Up

The data base contains the names of the operational and maintenance modes, their required control settings, and images of the appropriate front panels, in each state (these may include test equipment set-ups).

Instruction and Assistance. AIDE instructs and assists by listing required settings on the CRT and presenting images of the front panel properly set up, for each mode.

Drill. During drill, the technician is required to "set" the controls by touching the pen to the proper settings. As the pen touches a setting mark or label a new image is projected showing the switch set to the new setting. After the technician completes his set-up AIDE evaluates his work, indicates errors, and requires that corrections be made.

Troubleshooting

Assistance. The routines for assisting troubleshooting operate in cooperation with the technician to locate a malfunction. In the fully-supported condition AIDE provides all directions, which the technician carries out on his failed equipment. In less fully reported conditions, the technician requests particular advice. The assistance which is available consists of:

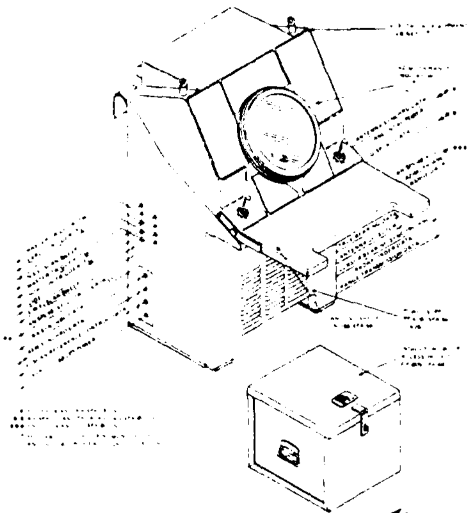
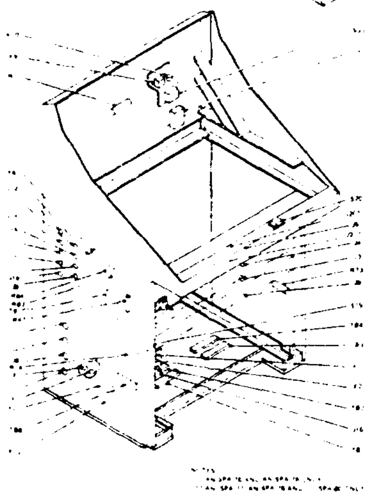
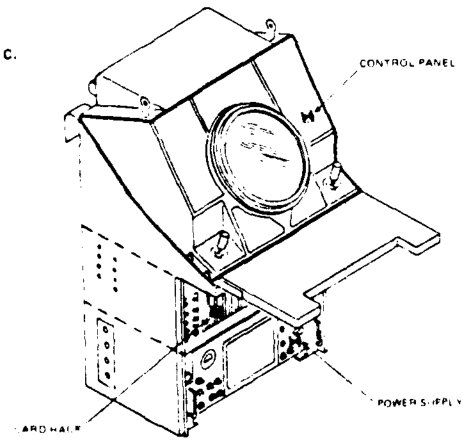
1) recommended next test to perform

2) displayed explanations of how to perform the test (if available in the data base)

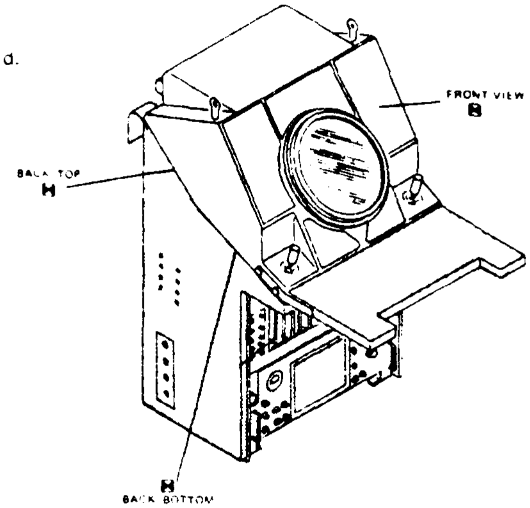
3) interpretation of the implications of the symptom in terms of the fault areas confirmed or suspected.

The above cycle is repeated until the process terminates at some, hopefully small, fault area. As with virtually all troubleshooting aids, this type of interaction will be sensitive to technician errors, and to "nasty" faults (such as multiple failures) which are not accurately isolated by the scheme provided. The likelihood of technician errors is reduced somewhat, however, since he "reports" the symptom by identifying a pictorial image which matches the observed symptom. And, since AIDE interprets each new symptom in terms of the elements which are suspected or eliminated from suspicion, the technician can gain insights into the hardware-symptom relationships even when the interactive process does not succeed.

Instruction and Drill. As noted above, a technician may find that working real or imagined troubleshooting

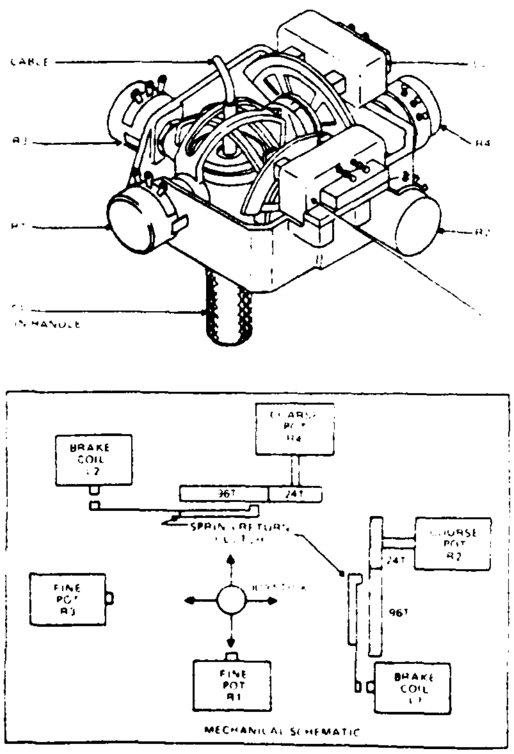
Projected Image	Comment
a. 	This is the "Top Level" picture - little detail is shown. Three more images are shown of this entity, a full color photograph (not shown here) plus images b and c, below.
b. 	Technician touches NEXT IMAGE on command menu.
AN/SPA-66 Indicator	Technician touches NEXT IMAGE.
c. 	The technician wants to look inside the unit, behind the control panel - he touches on the control panel, and sees image d.
AN/SPA-66 Indicator	

Projected Image	Comment
d.	Touching Front View would produce a full color close-up of the front panel, each section of which may be selected and 'operated' (described later).
	The technician wishes to see behind the front panel - he touches BACK, BOTTOM and receives a photograph of the interior (not shown here). He touches the label, Cursor Origin Joystick, and sees image e.



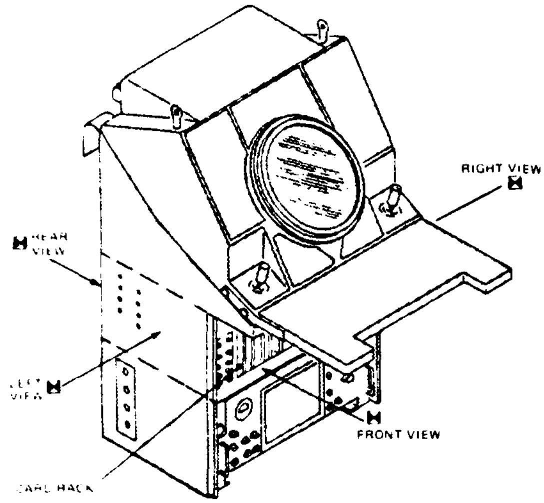
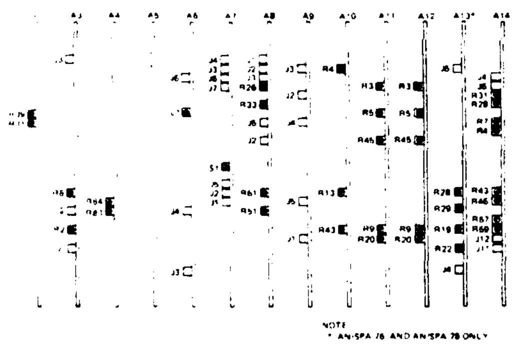
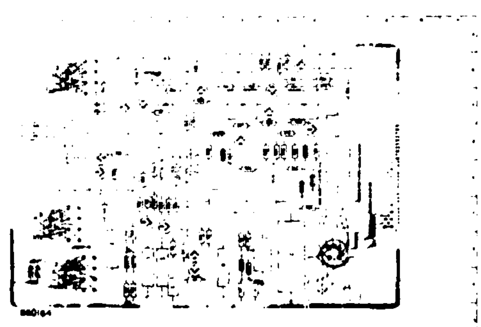
e.

Since there are no symbols on image e, the technician can go no <u>deeper</u> into the joystick mechanism [1]. He touches 'UP' on the command menu and again sees the interior view. From here he could select any of the other sub-elements or continue UP again. Suppose he wishes to look at a circuit card - he touches UP, sees image d, touches UP again, sees image c, then touches CARD RACK and sees image f.



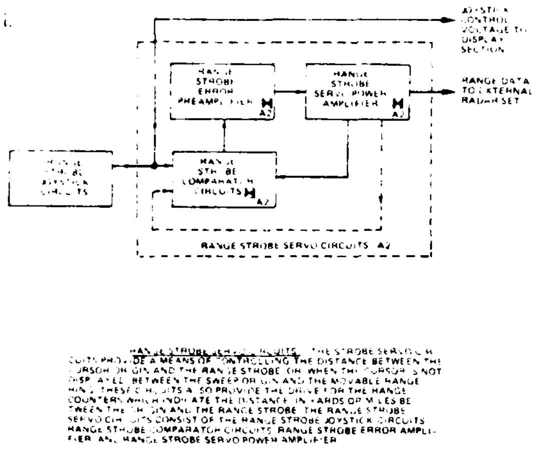
Cursor Origin Joystick, A20

[1] He can, however, request text which explains the purpose and theory of operation, as well as a functional diagram

Projected Image	Comment
f.  Card Rack	The technician touches Front view and sees image g.
g.  Card Rack, Front	Two additional images are shown, a color photograph and a labelled drawing. If the technician touches the ⧓ over board A2 on the labelled drawing, he sees image h.
h.  CHANGE 1	Three additional images are view; a color photograph, a part location index, and a pin number designation list. None of these contain a ⧓ thus no further hardware detail is available of the circuit board. Touching FUNCTIONAL APPEARANCE on the command menu, however, produces image i.

Projected Image | **Comment**

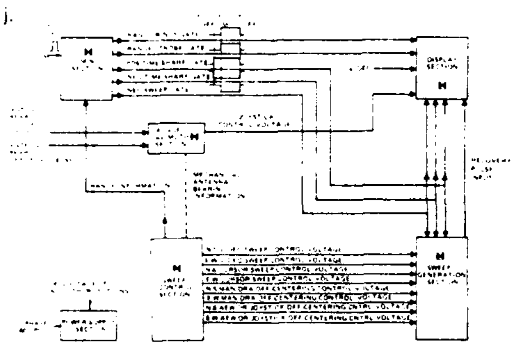
i.



Selecting any of the three sub-functions within A2 produces a circuit diagram at the component level (not shown here).

Repeatedly touching UP would now move the presentation to successively higher level functional diagrams, reaching the top at image j.

j.



INDICATOR, OVERALL FUNCTIONAL DIAGRAM

Touching PHYSICAL APPEARANCE on the command menu produces image a.

problems in the assistance mode does much to reveal the troubleshooting strategy of the content expert and underlying relationships between symptoms and functions. In the instruct mode the technician is shown the abnormal symptoms produced by each malfunction, or fault area, in the data base. In the drill mode the technician practices predicting the symptom at each indicator for each fault area. Note that the data base does not differentiate conceptually between operational units in a system and test equipment. Thus the content expert may involve in the troubleshooting strategy as much test equipment as might be available to the user.

DATA BASE

Obviously, if AIDE is to offer rich and detailed assistance and training the data base must be extensive. The current data base, developed just to test and demonstrate AIDE, contains great detail for just a few areas of the radar repeater, it contains just a few of the possible setups, and offers troubleshooting intelligence in a small portion of the equipment. This data base contains 125 images, approximately 50 of which were taken directly from existing technical manuals. It is estimated that a complete, detailed AIDE data base for the AN/SPA-66 would involve

approximately 1000 images, with perhaps one-quarter taken directly from the technical manual, one-half taken from the actual equipment, and one-quarter taken from specially prepared diagrams and text. Fortunately, some factors mitigate the human labor required to produce such a product, as follows:

1) The content expert is free to greatly expand areas of the equipment which are especially difficult and put less effort into other areas.

2) The content expert may choose those AIDE capabilities most valuable for the intended use, i.e., he may omit all troubleshooting data, or supply only troubleshooting data.

3) The content expert is only concerned with describing the target equipment; he need not devote effort to considerations of sequence of instruction, test questions, remedial paths, etc.

4) The majority of images require little or no preparation; they are of existing material or the actual equipment.

The fact remains, of course, that a substantial volume of photographic work is involved, requiring perhaps several man-months of effort. For expensive operational systems, this cost would be quite acceptable compared to the cost of using either the actual system or a special-purpose simulator for training purposes.

Data Base Requirements

The content-expert may decompose the equipment into any units which he feels are accurate and useful for understanding. AIDE requires a physical breakdown, a functional breakdown, and a cross-reference between the two.

A small portion of the physical structure data for the AN/SPA-66 radar repeater is shown in Figure 3.

NAME	IMAGE No	No IMAGES
1. AN/SPA-66 Radar Repeater	1	4
1.1 Control Panel	5	1
1.1.1 Front View	6	1
1.1.1.1 Power & Radar Select Group	7	1
1.1.1.2 Cursor & Sweep Function Group	8	1
⋮	⋮	
1.1.1.13 Plan Position Indicator	19	1
1.2 Card Rack	20	3
1.2.1 Card A2- Range Strobe Servo Amplifier	23	4
⋮	⋮	
1.2.13 Card A14- Sweep Generator	71	4
1.3 Power Supply	75	3
⋮		

FIGURE 3. A Portion of the Sample Data Base

The content expert supplies a photograph[2] of each element in the physical hierarchy and a photograph of each functional diagram in the functional hiearachy, plus whatever pages of explanations concerning the purpose and operation of these system sub-elements he desires. Note that information supplied by the content expert is not designated specifically for assistance, instruction, or drill. The monitor program handles all retrieval and presentation of the supplied content according to the requirements of the user.

During entry of the data base the content expert touches the pen to each defined sub-section of each photograph. This produces X-Y coordinates in the data base which allows the user to step through either hierarchy by touching the area of interest on the currently projected image. AIDE responds by projecting a close-up image of the sub-section selected.

As mentioned earlier, OJT and JPA for equipment operation and maintenance set-ups is produced by supplying names of controls, setting names, mode names, mode descriptions (required control settings), and photographs of the panel(s) in each mode.

Troubleshooting training and aiding is generated by AIDE from a troubleshooting "tree" which specifies a detailed, conditional, fault-isolation approach of the content expert, photographs of normal and abnormal symptoms for each involved indicator (including test equipment), and explanatory text to assist in performing and interpreting tests.

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Rigney, J. W. and Towne, D. M. Computer-Aided Performance Training for Diagnostic and Procedural Tasks, J. Educational Technology Systems, Vol 2(4), 1974.

Rigney, J. W. On Cognitive Strategies For Facilitating Acquisition, Retention, and Retrieval in Training and Education. (Tech. Rep. 78), Los Angeles, University of Southern California, Behavioral Technology Laboratories, January, 1974.

[2] *Currently, these are in the form of 35mm color slides. Color microfiche capability is being added.*

Small Systems World, Computer in a Suitcase, October 1978, Pg. 37.

BIOGRAPHICAL SKETCH

Dr. Douglas M. Towne is the Director of Behavioral Technology Laboratories, University of Southern California. He has been performing research in the areas of computer-aided instruction, optimization and modelling of troubleshooting strategies, and automated analysis of human tasks for fourteen years, and has published approximately thirty papers in these areas. A professional I dustrial Engineer, Dr. Towne has also developed computer-based systems for analyzing manufacturing methods and performance times.

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